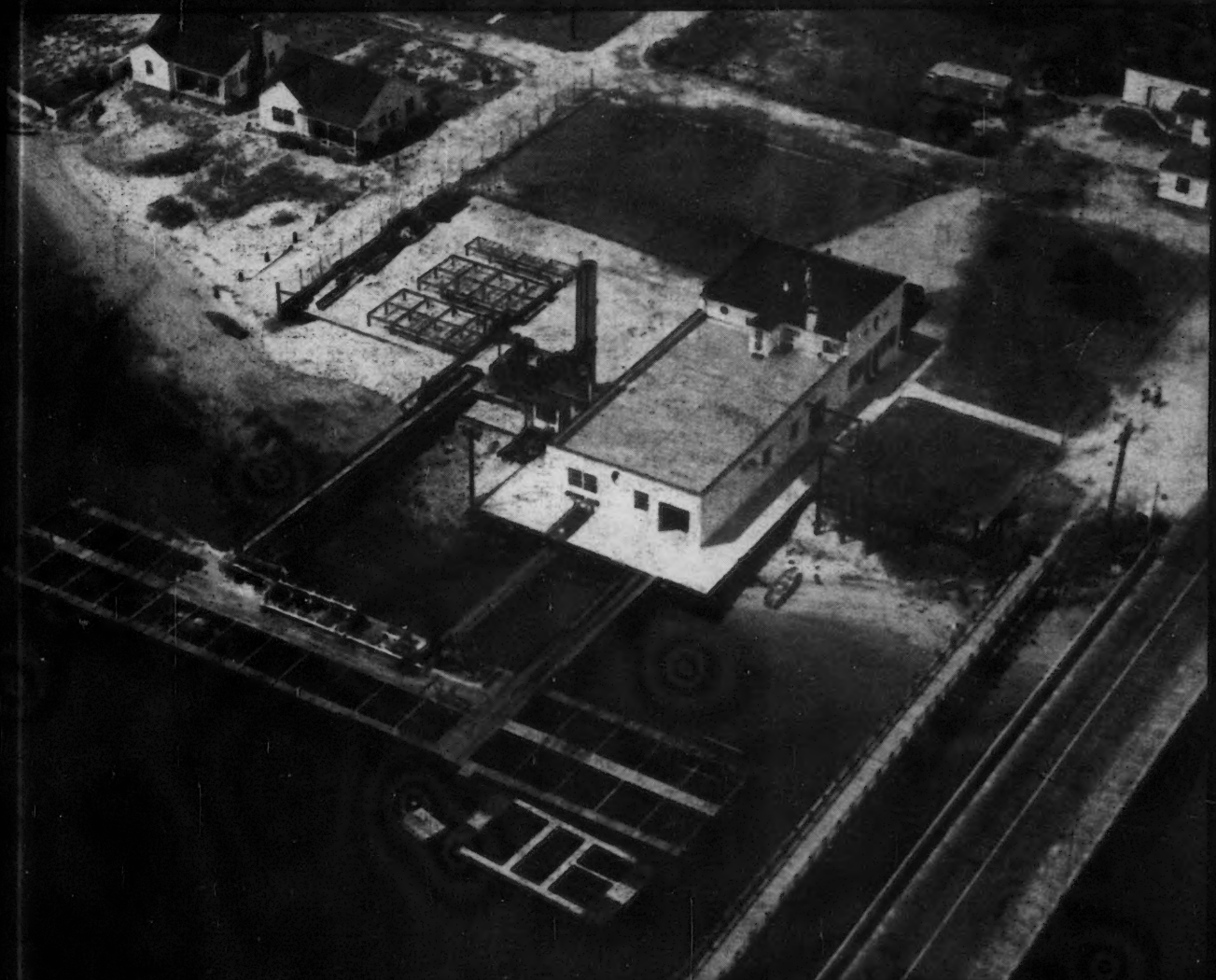
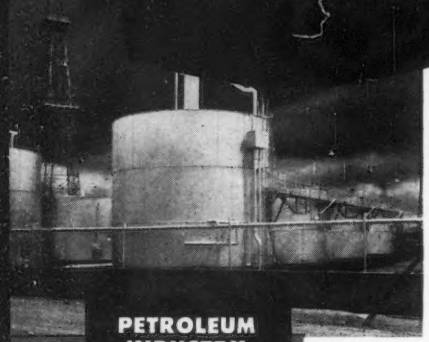
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



JANUARY, 1951

CORROSION PLAYS NO FAVORITES



PETROLEUM INDUSTRY

MEAT PACKING

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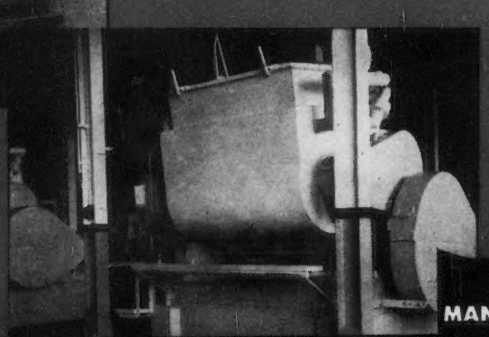

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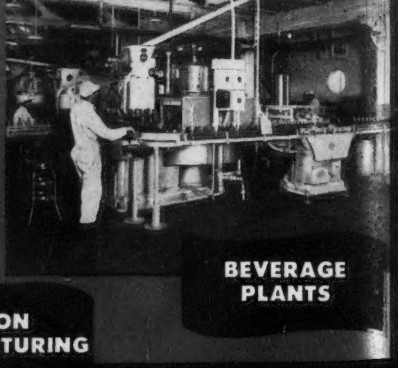

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...you have no other choice

No business escapes the effects of corrosion. It costs industry over $6,000,000,000.00 annually. Yet much of this costly damage might be avoided by taking just two simple steps—

1. Check the danger points in your plant—manufacturing equipment, piping, valves, tanks, motors, and all similar items.
2. Protect them with Amercoat—the corrosion-resistant coatings; each designed to meet specific conditions.

Most conventional coatings fail when corrosion threatens, because they are neither designed nor suited for severe service. Don't risk needless loss—protect now with Amercoat.

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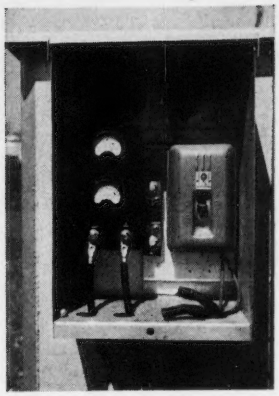
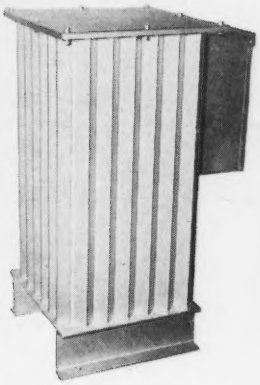
DEPENDABLE . . EFFICIENT . . LONG LIFE

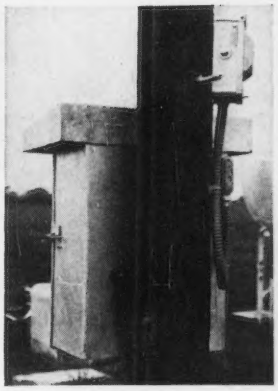
Cathodic Protection



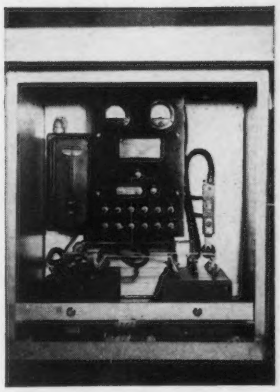
Oil-immersed, selenium rectifier —field installation showing meter and terminal box.



The NEW Westinghouse oil-immersed selenium rectifier—a 24V, 90 amp. unit just 43 inches high overall—36 gallons of oil suffice where 150 gallons were required in identical units of previous design.



Brance-Krachy air-cooled selenium rectifier in location showing pole mounting. (Method of connecting dc and ac leads optional.)



Typical unit construction—Brance-Krachy air cooled, selenium rectifier. Note sturdiness and easy accessibility.

OIL IMMERSED RECTIFIERS

Westinghouse selenium rectifiers have long been recognized for their quality featuring:

- ★ 11 ga. plate construction, bonderized—completely weather proof.
- ★ Large meter and terminal box easily accessible for making connections and reading meters.
- ★ AC circuit breaker equipped with heater type thermal overload relays.
- ★ Unitized construction of power unit for easy removal and inspection.

AIR-COOLED RECTIFIERS

New design features in Brance-Krachy air-cooled, selenium rectifiers are scaled to meet the demand for compactness and ruggedness in construction in this type of unit. These rectifiers are unsurpassed in quality, yet economical in terms of initial investment and years of trouble free performance. They feature:

- ★ 11 ga. plate construction—bonderized, or hot-dip galvanized after fabrication — case completely insect proof.
- ★ Fansteel selenium stacks—normally derated for operation at 60° ambient temperature for extra stack life.
- ★ AC starter—heater type overload protection.
- ★ Heavy duty transformer construction with strap type secondary top changer. We will build the unit to meet your requirements.

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ADD VALUABLE YEARS OF LIFE AND SERVICE WITH B-K PACKAGED PROTECTION UNITS

Brance-Krachy complete package-type protection units include either copper oxide or selenium, air-cooled or oil-immersed rectifiers, underground "trench wire," graphite and carbon anodes and coke breeze backfill. Complete cathodic protection installations sent to your job as a unit. ALCOA magnesium anodes and M. C. MILLER'S MULTI-COMBINATION METERS in stock. We have all accessories for installing any type cathodic protection installation.

WE WILL BUILD THE UNIT TO MEET YOUR REQUIREMENTS

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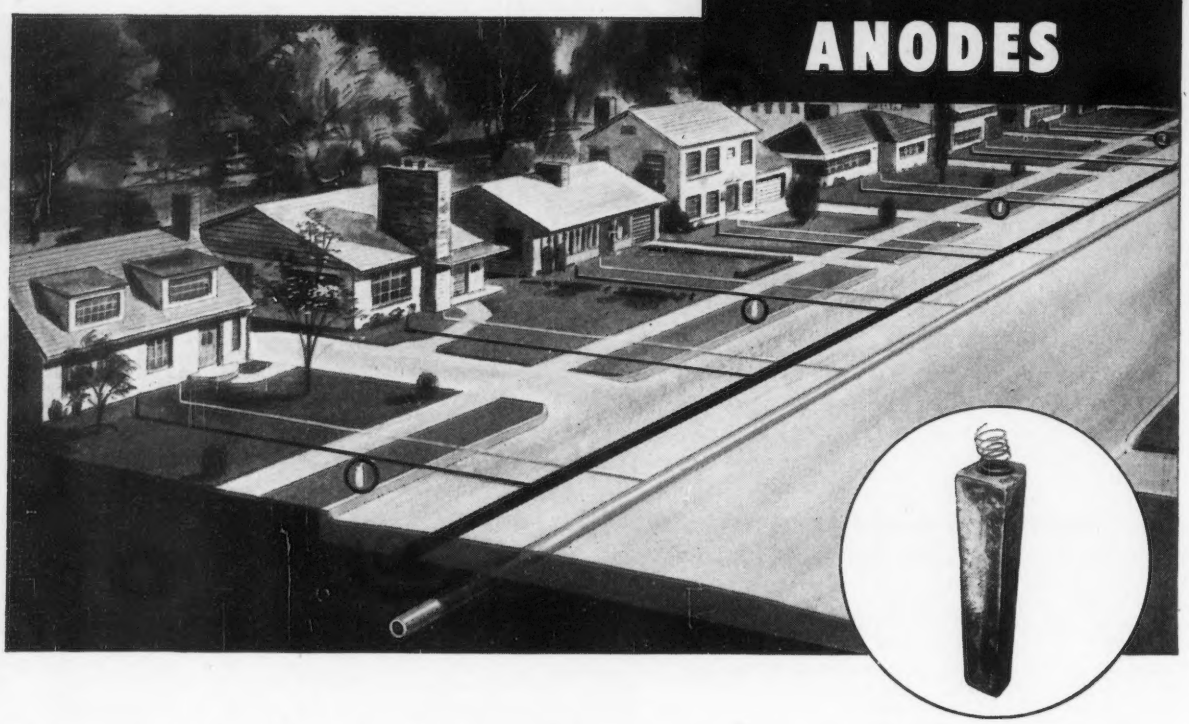
DOWELL MAGNESIUM ANODES



Underground distribution systems can now be protected from corrosion without accelerating metal loss on adjacent structures. Here is a case where leaks were effectively reduced with a low-cost, easily installed system of Dowell Magnesium Anodes.

This was a water distribution system in a municipality of 800 homes. Three years after the water lines were laid down, leaks began occurring rapidly—*18 in a period of three months.* Then Dowell Magnesium Anodes were installed . . . and, in the year and a half after installation, *not a single new leak was reported!* Results like this prove that Dowell Anodes pay! Currently, magnesium anode protection is being applied to the gas distribution system in one of our largest cities.

Dowell Magnesium Anodes offer many advantages:

1. Low installation cost and no maintenance.
2. *Adequate protection without accelerating corrosion on other buried metal structures.*
3. Installation materials buried beyond reach of storms, fires or vandals.
4. No outside current required.

For a complete story on the installation described above and other valuable information, write Dept. 13 at Dowell.

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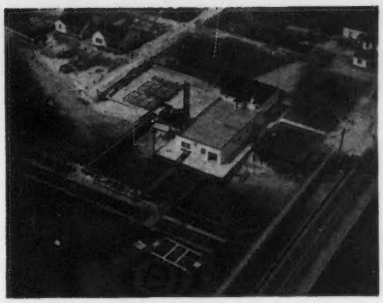
MAGNESIUM ANODES FOR CORROSION CONTROL



THIS MONTH'S COVER—This aerial view of the International Nickel Co., Inc., Harbor Island laboratory and corrosion testing station shows the testing racks in the foreground and the new laboratory building. Atmospheric test racks may be seen adjacent to the laboratory building. The test station was removed to this new site 15 miles north of Kure Beach because of storm damage to jetties there through which sea water entered the basin. Over 100 companies engage in cooperative testing.

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Corrosion

devoted entirely to **CORROSION** *research and control*

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Vol. 7 JANUARY, 1951 No. 1

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February—Pre-Conference Issue with round up of matters pertaining to the conference program.

March—Annual directory of membership.

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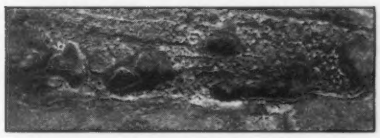

Neither was removed until November, 1949, when these pictures were made. After more than ten years' continuous immersion, with the results you see on bare steel, the vinyl film remained tightly bonded and the metal beneath, sound and dry.

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Dampney Vinyl Coating air dries in one hour . . . the surface it adds to metal is odorless, tasteless, nontoxic and non-flammable . . . it is as effective at and above the water line as it is below.

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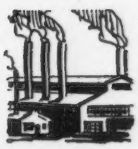

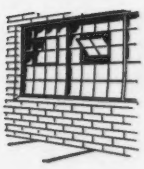

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

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(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Objectives and Progress of TP-2– Galvanic Anodes for Cathodic Protection

By WALTER P. NOSER*

THE GALVANIC ANODE Committee was formed to investigate the use of aluminum, magnesium and zinc as galvanic anodes for cathodic protection of metal structures in soils or in solutions.

The effect of such factors as anode composition and impurities, back-fill composition, installation practice, soil characteristics, weather and time on anode performance are being investigated.

W. P. NOSER

"The First Interim Report on Galvanic Anode Tests" has been published and is available at a nominal charge from the NACE. A condensation of this report appeared in August, 1950, issue of CORROSION. The report covers information furnished to the committee by its members up to early 1949.

Tests have been started under the auspices of the Auminum Company of America, Colorado Interstate Gas Company, Dow Chemical Company, Ebasco Services, Houston Pipe Line Company, Humble Pipe Line Company, Montana Power Company, Public Service Company of Northern Illinois, Service Pipe Line Company, United Gas Corp., and the United Gas Pipe Line Company.

A sub-committee has been formed with Lyle Sheppard as chairman to correlate operating data on anodes installed by companies where testing procedures and measurements may differ from committee procedure.

Committee membership is open to companies wishing to enter the cooperative tests or wishing to furnish data from anodes installed under operating conditions.

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Combating Corrosion in a Chemical Plant With Magnesium Anodes*

By OLIVER OSBORN

TO THE PERSON who is familiar with the development and growth of the chemical industry, corrosion has appeared as an ever present and costly enemy. In fact, corrosion has been so ever present that plant policies have verged on "production in spite of corrosion" instead of "production without corrosion." Today, however, competitive practices throughout the industry are forcing the abandonment of such policy, since expenditures which were formerly used to appease the ravages of corrosion must now be eliminated to assure a reasonable margin of profit.

It cannot be overemphasized that the cost of corrosion in a chemical plant is tremendous. For example, it is estimated that expenditures in the Freeport plants of The Dow Chemical Company chargeable either directly or indirectly to failures in materials of construction are in the order of millions of dollars per year. Obviously the magnitude of this figure, indicates solution to a great number of problems is yet to be found.

Methods of Controlling Corrosion

Selection of the proper material of construction is often the best solution to a problem. In other cases the answer may be in the use of a protective coating. And where the corroding structure is underground or in aqueous media cathodic protection is generally also an important consideration.

Cathodic protection current may be generated from external power sources, may be obtained by rectification of AC power or by the use of galvanic anodes. In recent years there has been a marked increase in galvanic anode applications which has been brought about by the fact that the galvanic anode possesses certain fundamental advantages over other power sources in a number of types of installations.

The galvanic anode is sometimes termed as "packaged power" and it is this characteristic which makes possible its use in locations remote from electrical facilities. Another advantage of the galvanic anode lies in the fact that in applications with limited power requirements it may be installed at considerably less cost than an external power source of comparable size. Still another advantage of the galvanic anode lies in the fact it can be employed in locations at which for reasons of safety or accessibility other methods of cathodic protection can not be considered.

Magnesium as a Galvanic Anode

Magnesium has been well established as an excellent galvanic anode material because of its high position in the electromotive force series of metals, its high electrochemical equivalent in ampere hours available per pound of metal and its ability to maintain high current output throughout its entire life as an anode.

High purity Hl magnesium alloy which is generally used as an anode material will exhibit a half cell potential of 1.55 volts when referred to a $Cu-CuSO_4$ electrode. Thus when it is coupled to unpolarized steel in seawater (potential 0.60 volts) the resulting battery will have a potential of about 0.95 volts (1.55-0.60 volts). The total useful current which may be expected from this alloy has been found in practice to be from 500 to 600 ampere hours per pound depending on the current density and environment in which it is operated.

Fortunately, magnesium does not exhibit anodic polarization tendencies; consequently, there is no diminution of current with time from this cause. Neither is there any reduction in current with time due to the building up of a non-conducting corrosion product.

Installation Design

Flexibility in installation design may be had be-

OLIVER OSBORN is a native Texan and a graduate of Texas A. & M. with a BS in chemical engineering. For the past ten years he has been with Dow Chemical Company. Presently he is in charge of the Electrochemical Engineering Department of the Dow Texas Division. Mr. Osborn has been active in an extensive program for development of uses of magnesium for cathodic protection. He is currently chairman of Houston Section, NACE.

Abstract

Cathodic protection of steel and cast iron in a chemical plant is economically justified and feasible from an engineering point of view under certain conditions. Magnesium anodes are useful under conditions which meet are restrictive as to space and accessibility. Principal use of magnesium anodes for cathodic protection of portions of the Dow Chemical Company's Freeport, Texas, plant were in structures handling large volumes of sea water and brine both static and in motion. Studies indicate the cost of the remedial measures is much less than would be the cost of replacing structures corroded to destruction, even when considerations of uninterrupted service, loss of production from down time and other factors are disregarded. Experimental installations are being studied and new aspects of the possibilities are constantly being investigated.

★ A paper presented at a meeting of South Central Region, National Association of Corrosion Engineers, Dallas, Texas, October 3-4, 1949.

cause of the availability of a number of different anode sizes and shapes. This permits the use of an anode which will deliver the desired current for the condition encountered and also allows the selection of a shape adaptable to the structure being protected. In general, anode shapes having greater surface areas will have a higher current output, and those having greater metal volume to surface area ratios will have a longer life.

Types of magnesium anodes generally used in aqueous media are shown in Figure 1. The 51-pound 8-inch x 16-inch cylindrical anode (Type 5C) is cast around a ⅜-inch pipe core in order to permit the threading of a wire cable through it and thus facilitate the suspension of a number of anodes from a single cable. This anode finds particular application where high currents are needed in low resistivity media. The 17-pound 4-inch x 20-inch "D" shaped anode (Type 1B) contains a ⅛-inch x 4-inch pipe core cast in one end to which an electrical connection can be made, or by drilling the anode it may be bolted, flat side down, directly to the structure to be protected, which thus enables the installation to withstand high liquid velocities. This anode is adaptable to more confined spaces than the Type 5C. The "Galvo-Rod" is an extruded anode with a continuous No. 13 iron wire core. It is available in ½, ¾ and 1-inch standard pipe sizes and in lengths up to 20 feet, and is used in confined spaces or in high resistivity media. The "Galvo-Line" is an extruded ribbon type anode also containing a continuous No. 13 iron wire core and is available in banded coils up to 1000 feet in length, (longer lengths are available on reels). Due to its flexibility and size, it finds application in very confined spaces. It is also used in very high resistivity media, or in low resistivity media where it is desired to obtain very high currents for short periods of time.

Figure 2 presents the relationship between anode output or anode life and media resistivity for the different types. This information will assist the designer in selecting the proper anode for the job under consideration. The practice of grouping a number of anodes on a single installation will somewhat reduce the current output values shown. However, in general, when lead resistance is negligible and the cathode bare, the magnitude of reduction is under 15 percent if the spacing between the anodes (in feet) are greater than the number of anodes employed in the group.

To design an installation, the corrosion engineer will first determine medium resistivity and estimate the total current required for protection. He will then decide on the anode shape which may be fitted most conveniently into the structure to be protected. Reference to Figure 2 will next show what the current output of the anode type chosen will be and also its expected life. Knowing the current output per anode and the total current required for the entire structure, the total number of anodes to be installed can be arrived at easily.

Occasionally the designed-for life of the installation will be shorter than periodic plant inspection shutdowns. etc., and under this condition electrical

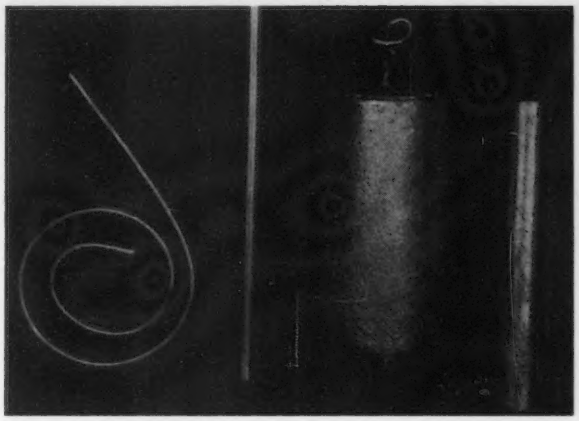

Figure 1—Types of magnesium galvanic anodes: 1—⅜-inch by 3/16-inch Galvo-line, 0.22 lb./ft. 2—1.315-inch diameter Galvo-rod, 1.1 lb./ft. 3—8-inch by 16-inch Type 5C, 51 lb. 4—4-inch by 20-inch Type 1B, 17 lb.

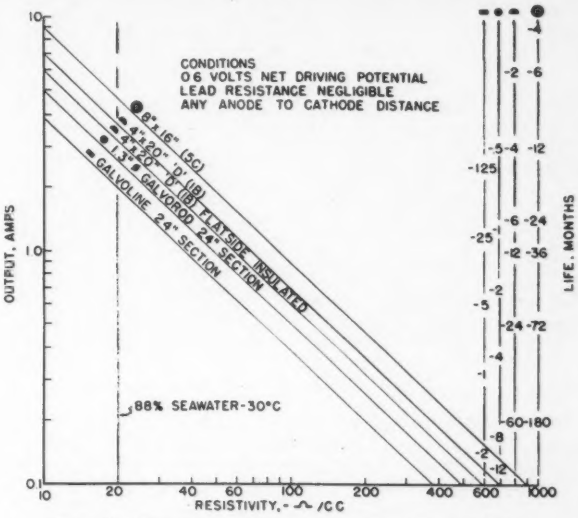

Figure 2—Magnesium anode output versus water resistivity.

resistors of suitable values may be installed in the anode circuits to slow them down to the desired drain.

Through the use of ingenuity in making anode attachments, a great variety of submerged metallic structures may be protected. About the only limiting factors are: 1) that sufficient space adjacent to the structure be available for the placing of the anode where it will not seriously interfere with fluid flow; 2) that the electrolytic resistivity of the medium be low enough to allow sufficient current flow from the anode to supply cathodic protection; and 3) that cathodic protection be an economical solution to the problem. In Dow's Freeport plants there are a great number of structures such as steel flumes, heat exchanger boxes, process vessels, etc., handling sea water or chemical solutions, where cathodic protection with magnesium has solved severe corrosion problems. The discussion to follow will describe a number of such installations.

Sea Water Flume

In one application, 250,000 gpm of sea water used

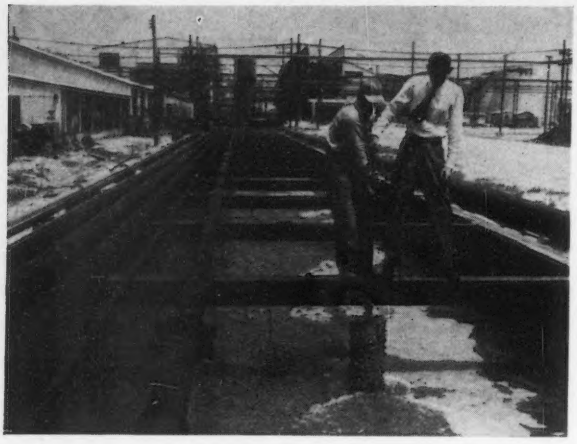

Figure 3—Magnesium anode suspended in flume of flowing sea water.

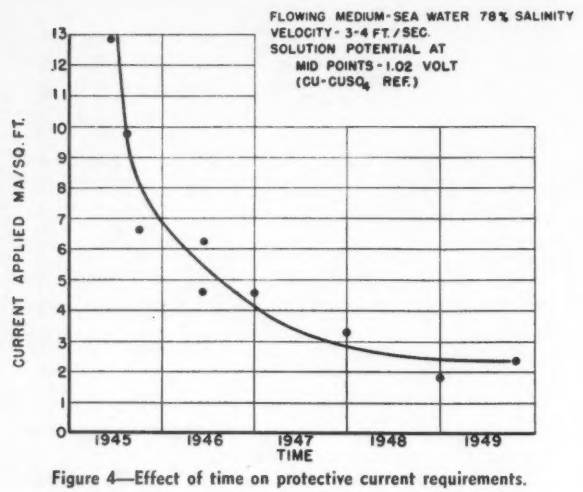

Figure 4—Effect of time on protective current requirements.

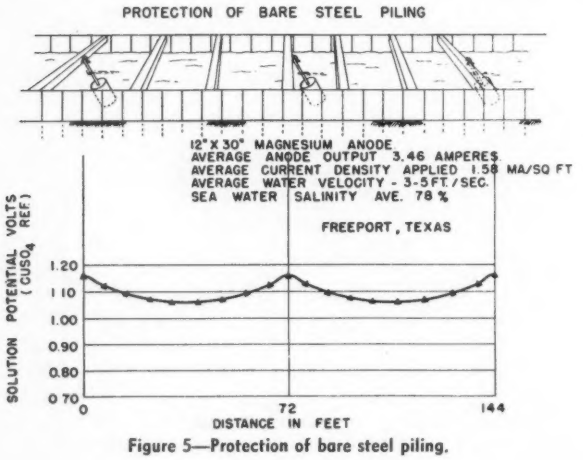

Figure 5—Protection of bare steel piling.

for cooling and as a raw material in the manufacture of magnesium and bromine are transferred through the plant in a submerged 12-foot x 18-foot rectangular flume 2300 feet long whose sides are constructed from steel sheet piling. The corrosion rate of steel under these conditions was severe. Consequently, it was obvious that some means of protection had to be supplied. Paint coatings were expensive and could not be used below the water line, because at no time was the flume out of service for their application. Consequently, as a possible solution to the problem a full scale experimental magnesium installation was made. The job was completed in 1945, and since that date close observations have shown the installation to be highly successful, both economically and from the standpoint of supplying protection to the steel.

As Figure 3 shows, the installation consisted of suspending special 200-pound anodes in the center of the flume at 32-foot intervals, suspension being accomplished by welding steel rods to the anode cores and then attaching the rods to flume cross members through a hook and eye arrangement, which thus eliminated undue strain on the attachment by allowing freedom of movement of the anodes in the water. Because the protective effect of the magnesium does not extend for any appreciable distance above the water line, the portion of the piling subject to atmospheric corrosion was protected with a hot coal tar enamel.

A number of interesting observations have been made on the installation, one of the most notable of which is the manner in which the current required to maintain protection has steadily reduced with time.* As Figure 4 indicates, the initial 13 ma/sq. ft. gradually reduced over a 4-year period to a value of little more than 2.0 ma/sq. ft. This decrease is explained by the fact that a protective calcareous deposit of calcium and magnesium salts normally present in the sea water was gradually precipitated on the surface of the metal because of the alkaline environment produced thereon by the cathodic protection current. This phenomenon appears to be a very important consideration in the design of sea water installations, since it indicates that ultimate current requirements will be considerably less than initial requirements.

Another interesting observation has been in regard to the very uniform current distribution which is obtained with time, as evidenced by the flat solution potential curve of the steel, shown in Figure 5. This curve presents data from a new installation completed in 1949 in which anode spacing was at 72-foot intervals. This spacing represents an anode-to-cathode area ratio of about 1 to 150.

The economics of this installation are rather astounding. It is estimated that an annual expenditure of $1000 for magnesium indefinitely extends the underwater life of the steel. However, if such protection were not applied, projected underwater life of the flume would be about 15 years and the replacement costs would then amount to about $17,000 per year, exclusive of lost production time incurred by the failure. Such a comparison in cost leaves no question as to the magnitude of savings rendered by this installation.

* Incidentally, it has been found that a structure potential of at least —0.85 volts (Cu-$CuSO_4$ reference) is a satisfactory criterion for protection.

Condenser and Heat Exchanger Water Boxes

Highly satisfactory results have been obtained from making magnesium installations on the cast iron and steel water boxes of a great variety of condensers and heat exchangers handling sea water.

In regard to design considerations, installations generally have employed the 17-pound D-shaped anode which is drilled and bolted directly to the structure being protected. Where clearances do not permit such a large anode, the "Galvo-Rod" has been used, with attachment being made through some form of clamping arrangement. Wherever possible the anodes are placed near corners or pockets in order to facilitates the current entering the more inaccessible areas.

Some interesting observations are cited on one of our larger power plant turbine condenser boxes which has been under experimental protection with magnesium for some 3½ years. This cast iron water box is about 14 feet in diameter and 3½ feet deep. Water flow is estimated at 72,000 gpm.

Prior to the time when magnesium was installed there was evidence of very severe graphitization and corrosion was confirmed further by the presence of large masses of mushy, red rust which could be sloughed off the surface of the cast iron easily. After the magnesium had been in operation for a few months, however, the action of the current caused all of the old corrosion product to exfoliate, and the result was a clean surface covered with a thin protective calcareous coating.

The installation was made by attaching 17-pound D-shaped anodes (Type 1-B) to the water box walls at convenient locations by the method as shown in Figures 6 and 7. Particular attention was paid to sealing of the head and contact nut bolt by filling recess with a waterproofing material, because water penetration into this area could cause failure of the electrical connection between the magnesium and securing nut.

Average spacing of the anodes was at intervals of about four feet on the circumferential wall. This was equivalent to a coverage of about 40 sq. ft. per anode. Under these conditions the anodes were found to last about six months.

In order to study the effectiveness and coverage of the cathodic protection, an experiment was set up in the condenser box in which a rack of cast iron coupons was installed adjacent to a single anode. Figure 8 shows the condition of the coupons after 100 days' exposure. (The anode was located to the left of the rack). The severity of the corrosion on the coupons too far away to receive protection from the magnesium is striking when compared to the excellent condition of those near the anode. Under conditions of the test protective coverage was found to extend about 2 feet from a single anode.

A typical heat exchanger head application is shown by the sequence of pictures in Figure 9. In sea water service, the cast iron baffle plates in this 30-inch exchanger failed after less than two years of service (left-hand picture). A similar head was protected with magnesium, as shown in the center picture, and

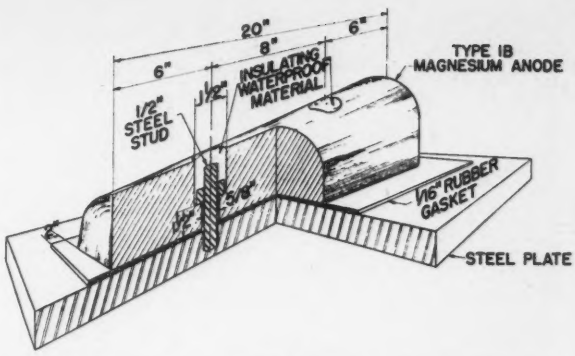

Figure 6—Magnesium anode installation for heat exchanger boxes.

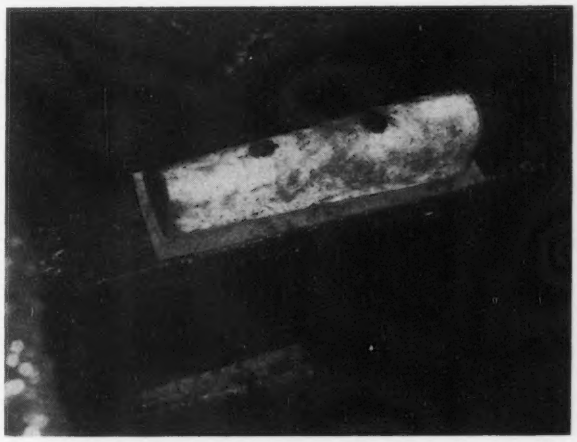

Figure 7—Anode in condenser box.

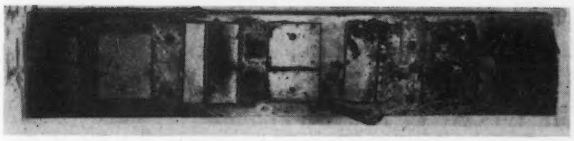

Figure 8—Cast iron test coupons in a condenser box.

the right-hand picture shows the condition of the head when inspected after two months' operation of the magnesium. Particularly significant in the latter picture is the protective calcareous coating which had been laid on the surface of the metal. This was one of the early magnesium installations, and the anodes were prepared by cutting half-round sections from a 4-inch x 20-inch cylindrical anode. Present practice employs D-shaped anodes or sections thereof attached in a manner similar to those described for the turbine condenser. Anode life on the installation illustrated was about four months. Life on the presently used D-shaped anodes is about six months.

Figure 10 shows companion cast iron water boxes for a turbine air cooler. The box on the left had been in service for four years, while the one on the right was a replacement box, protected with magnesium,

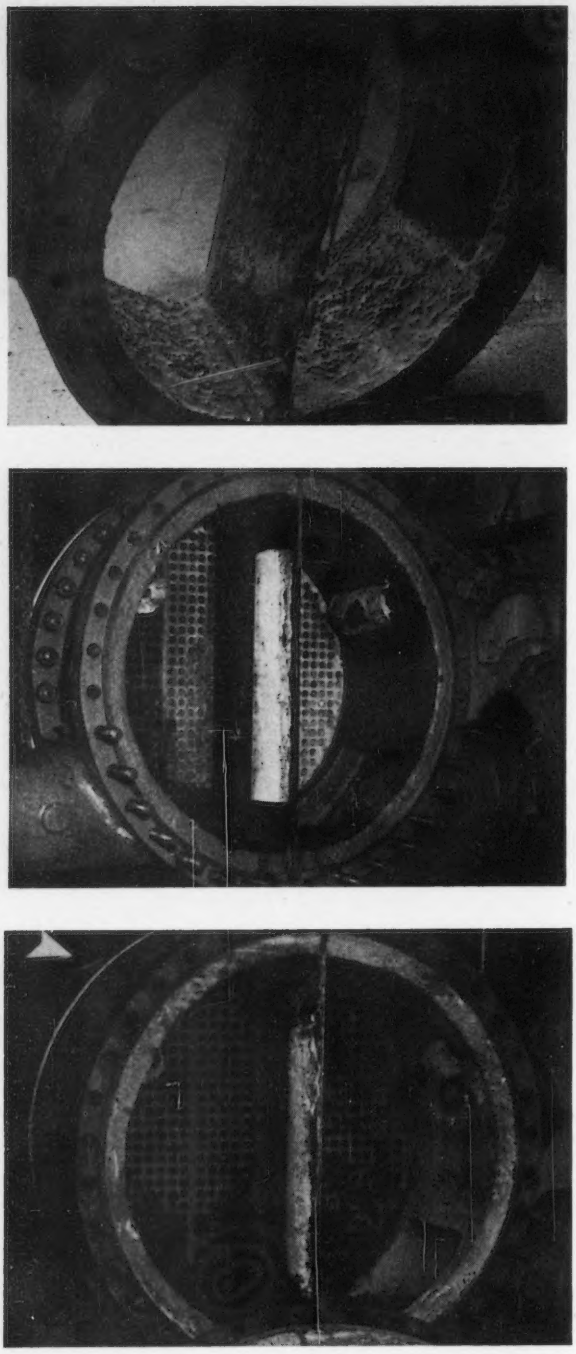

Figure 9—(Top) After less than two years, no anode. (Middle) Newly-installed anodes. (Bottom) After two months with magnesium anodes.

which had been in service for one year. Observation of the end of the separator plates will show the box containing the magnesium to be in excellent condition, while on the unprotected box corrosion has progressed almost to the point of failure of the plate. The cost of replacing the corroded box amounted to approximately $700, while it is estimated that the cost of supplying protection with magnesium for the same four-year period would be only $80.

Figure 11 shows a "Galvo-Rod" installation made on a water box in which there was insufficient space to permit the use of a larger type anode. A resistor was placed in the circuit in order to obtain the desired life, and insulation of the anodes from the cover plate so that the resistor could be effective was obtained by wrapping the points of contact with rubber tape painted with an insulating varnish.

Construction of the open-type condenser box permits a very simple magnesium installation, as shown by Figure 12. In this case the steel walls of a large open-topped cooler employing sea water as a cooling medium, are protected with 50-pound anodes (Type 5C) installed as shown. Life on the installation was 10 months, and applied current density to obtain protection was approximately 12 ma/sq. ft.

Tanks and Process Vessels

Protection with magnesium offers several distinct advantages over paint coatings when considering the internal protection of storage tanks and process vessels, because production schedules oftentimes do not permit the shutting down of equipment for painting, and in many cases environments are such that paint coatings are not practical. When one or both the above situations exist, magnesium very often may be used to solve the corrosion problem. Two of such cases are cited:

Figure 13 shows a 50-foot diameter concentrated salt brine storage tank in which the 8-inch x 16-inch Type 5C anodes have been employed for protection. The simple method of anode suspension used (Figure 14) often is employed where the use of this type of anode is applicable. Replacements can be made easily with the tank in continuous use. The current density required to obtain protection was found to be 8 ma/sq. ft., and the life of the installation employing 20 anodes was found to be about one year.

Figure 15 illustrates a magnesium installation in a reaction tank involved in one stage of the sea water-magnesium process. Protective coatings could not be employed here because of the high temperature and corrosivity of the environment. In this case, protection was obtained with magnesium anodes. Installation was made by suspending anodes from 20-foot hooked steel rods to permit their movement with the swirling liquor. Attachment of the rods to the anodes was made by welding them to a steel strap, which in turn was welded to the pipe sections extending from two anodes placed side by side.

A slightly different application of magnesium on tanks has been to use it in conjunction with paint coatings to supply protection to exposed areas caused by paint coating breakdown. Figure 16 shows an anode installation on the interior painted walls of a 125,000-gallon elevated fresh water tank. Protection was obtained with nine 4-inch x 60-inch (Type 4A) anodes suspended with insulated wires. The installation has been in operation over three years, and from the present average current output of 175 ma. per anode, the projected life of the installation is estimated at about 15 years. The applied current density is approximately 0.6 ma/sq. ft. There has been no indication that cathodic protection accelerated break-

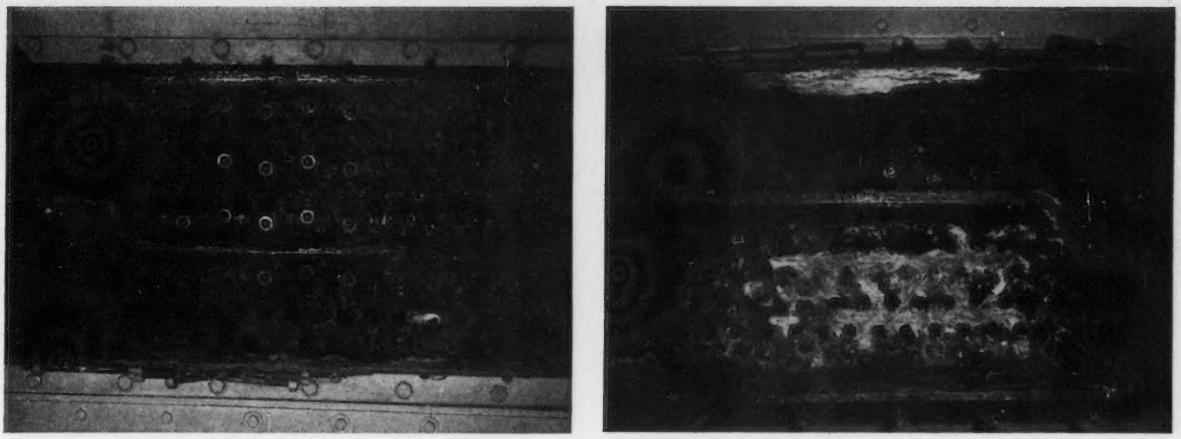

Figure 10—Cast iron water boxes for a turbine air cooler. (Left) After four years, no anode. (Right) Protected with magnesium anodes for one year.

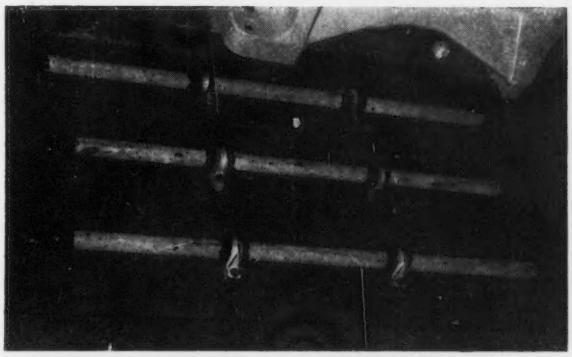

Figure 11—Magnesium rod installation in condenser box.

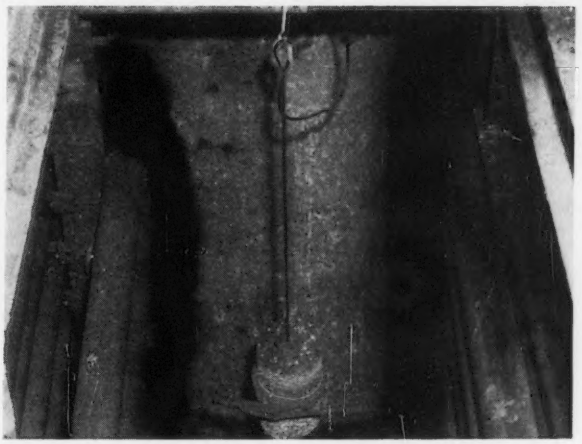

Figure 12—Magnesium anodes in an open-type condenser box.

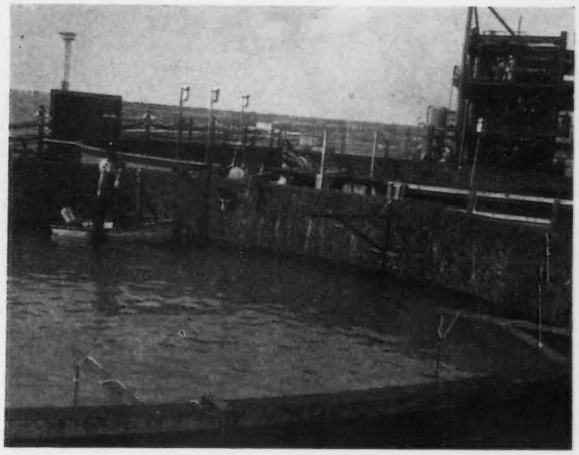

Figure 13—Salt brine storage tank with magnesium anodes.

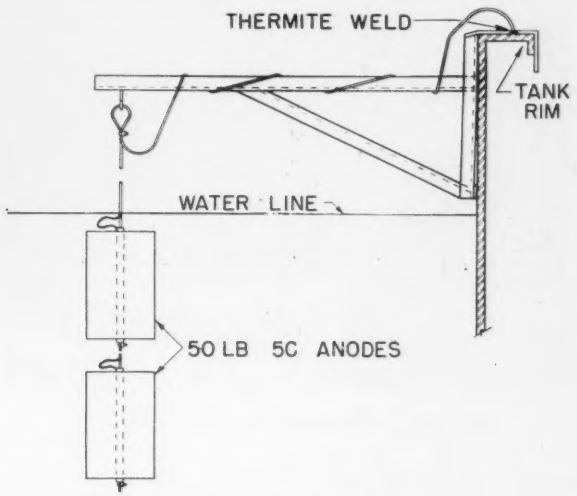

Figure 14—Typical type 5C anode installation.

down of the paint coating, because the current required for protection has remained essentially constant over the 3-year period. A water emulsion asphalt class type of coating was used.

It is to be pointed out that on fresh water installations, water composition has an important bearing on the ease at which protection may be obtained.[1] For example, in the installation just described in

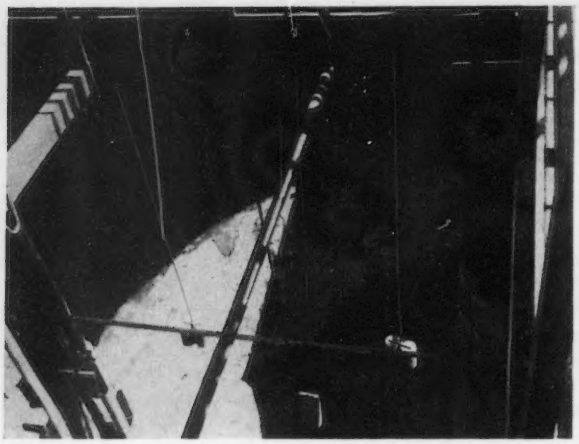

Figure 15—Magnesium anode installation in reaction tank.

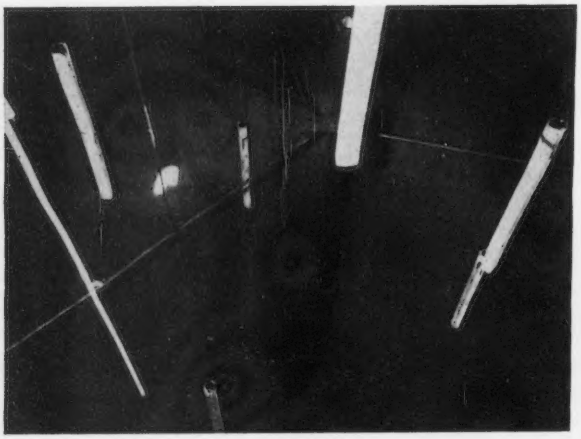

Figure 16—Anode installation in fresh water tank.

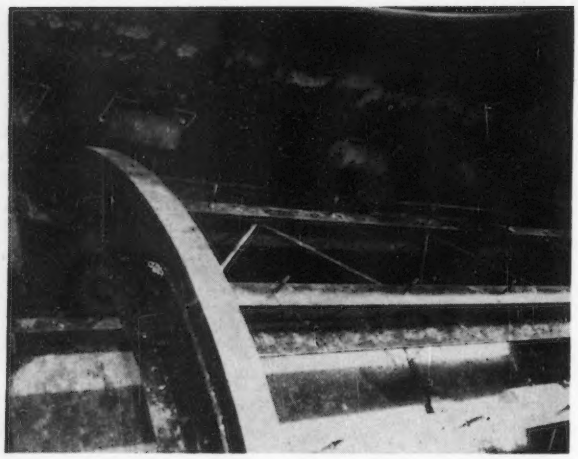

Figure 17—Anode installation on rotary screen.

which the concentration of each of the calcareous coating forming constituents, calcium and magnesium, was from 20 to 40 ppm and water resistivity was from 600 to 1000 ohm/cc, complete protection was readily obtained. However, in a similar installation in which the calcium and magnesium contents of the water were from 10 to 20 ppm and the resistivity was 1000-1500 ohm/cc, only partial protection was realized. This indicates that the design of fresh water installations ultimately rests on the type of water encountered in the case under consideration.

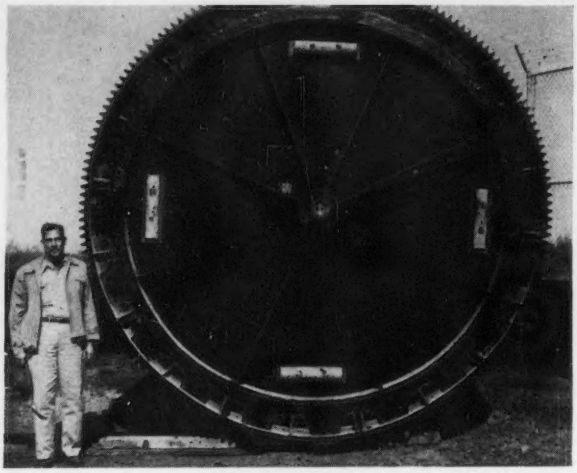

Figure 18—Anode installation on screen housing.

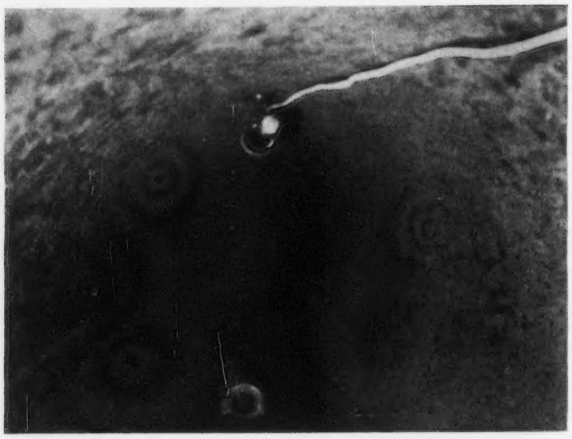

Figure 19—Anode installation in sea water flume.

Miscellaneous Applications

In addition to the structures already discussed which have been protected successfully, experience has shown that magnesium can render great savings when applied to many other miscellaneous types of chemical plant equipment.

Figure 17 shows rotary sea water screening equipment and enclosing steel sheet piling bay. Extensive failure of the piling and screen cage housing, due to the high velocity flow of sea water occurring after about six years' service, and repair of the damage done on six of these units entailed an expenditure of some $27,000. Magnesium was installed then to protect the repaired equipment with the anticipated cost of protection for six years being estimated at only $7000. The method of anode attachment used

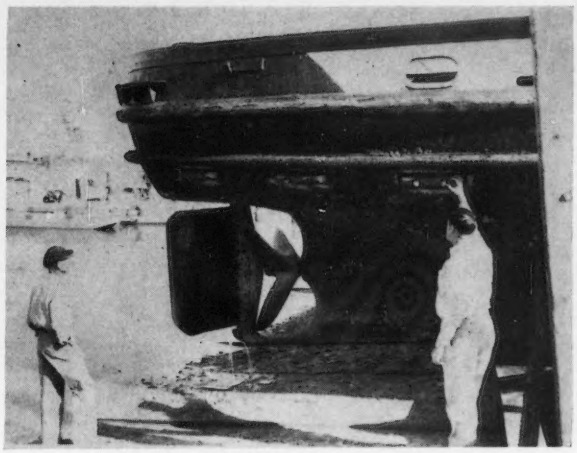

Figure 20—Anode installation on harbor tug boat.

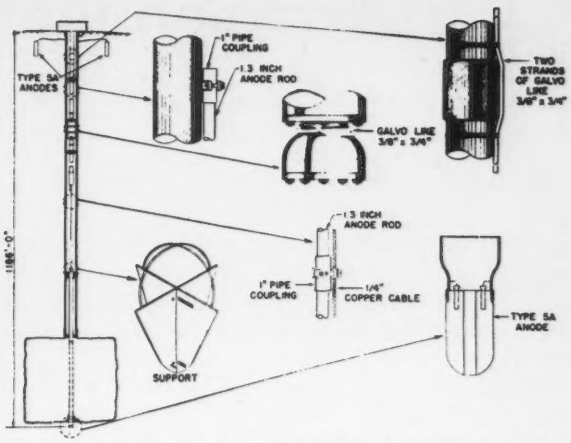

Figure 21—Cathodic protection of brackish water well No. 16 using magnesium anodes.

to maintain rigidity in high velocity water is noteworthy. Figure 18 shows the protection supplied to the steel screen cage housing by bolting D-shaped anodes to the cage at convenient locations.

Experimental

Possible new applications for magnesium are continually being explored. A few installations of particular interest on which performance data are still incomplete will be discussed briefly.

Figure 19 shows the inside of a 30-inch sea water line in which D-shaped anodes have been installed at 5-foot intervals. Over a 6-year period of service, the welds in this line had corroded so badly that a complete reconditioning was required. It is anticipated that the magnesium installation will supply protection for a considerable period.

Figure 20 shows a magnesium installation on the steel hull of a 43-foot harbor tug boat. Three 17-pound D-shaped anodes were bolted to each side at a point immediately below the bumper rail, the installation being at the time of dry docking for repainting the hull. A potential reading taken one week after launching at a point on the hull most remote from the anodes was found to be 1.17 volts (Cu-$CuSO_4$ ref.). This value is considerably in excess of that required for effective protection and it is hoped that this protection will be maintained for an extensive period.

Figure 21 shows an interesting installation made for the purpose of protecting the internal parts of a brackish water well. Recent failure of the casing and screen on a similar well caused its abandonment after 7½ years' service, and the drilling of a new well entailed an expenditure of over $19,000. In an effort to prevent the recurrence of such a failure, an extensive magnesium installation was made on all sections subject to severe corrosion.

It is to be noted that three different anode types were employed in order to meet best the space requirements in the different parts of the well. The outside of the screen section was provided with protection by suitably machining a 50-pound anode so that it might be screwed directly to the end of the screen. The inside of the screen and open casing below the pump was taken care of by suspending a continuous length of 1.3-inch diameter "Galvo-Rod" from the pump. This continuous suspension was accomplished by threading together 20 foot rods with conventional pipe couplings. Each coupling was then fastened with a water pipe clamp to a continuous copper cable along side the anode string in order to insure removal of the couplings after the anodes were expended. The pump housing proper was wrapped with "Galvo-Line" and protection of the pipe above the pump was obtained by lashing two strands of "Galvo-Line" to the pump tubing, as there was insufficient space in the annulus to permit the use of "Galvo-Rod."

Analyses for suspended iron in the water flow have indicated that favorable results are being obtained. However, a final evaluation cannot be made until the tubing and pump are pulled for inspection.

Summary

Extensive use of magnesium as a galvanic anode during a 4-year period in a large number of chemical plant applications has demonstrated its excellent properties in combating corrosion. Further, it has been shown that through the use of ingenuity in mechanical design, the corrosion engineer can adapt magnesium to a great variety of installations. And finally, data have been presented to show that maintenance expenditures were reduced to from ¼ to 1/16 of their original values after magnesium was used to halt the normal processes of corrosion.

Reference

1. Sudrabin, L. P., and MacDonald, E. P. Principles of Cathodic Protection Design. *J. AWWA,* **40,** (1948) May.

Corrosion Inhibitors for Steel*

By W. G. PALMER*

Foreword

By U. R. Evans, M.A., Sc.D., F.R.S.

Of the two main classes of inhibitors, neither is entirely satisfactory in preventing the corrosion of steel. The reasons have been discussed elsewhere.[1,2,3,4]

A cathodic inhibitor causes an otherwise corrosive water to throw down a sparingly soluble substance on the cathodic zone, as a result of the corrosion reaction. This layer, which is usually visible and which may be subsequently converted to a clinging form of rust by interaction with the anodic product, tends to slow down the reaction, but often the rate of corrosion becomes negligible only after an appreciable amount of attack has actually occurred. On the other hand, most cathodic inhibitors are "safe," in the sense that, if added in insufficient amount, the effect is no worse than if no inhibitive treatment had been attempted.

An anodic inhibitor is generally a substance which, when added to a ferrous salt solution, precipitates the iron.** There is some difference of opinion on whether the protective layer formed on the metal has the same composition as the precipitate thrown down in the manner described, but undoubtedly the presence, in water, of a substance which prevents the existence of iron ions in appreciable concentration, provides conditions favourable to the building up of a truly protective film, which is usually invisible. If added in sufficient quantity, an anodic inhibitor is usually very efficient—far more so than a typical cathodic inhibitor—but the quantity needed increases if the water contains chlorine ions (or other anions forming soluble iron salts). If too little is added, soluble iron chloride is formed at the most susceptible points, and reacts with inhibitor at a distance from the metallic surface, forming a loose blister, which prevents the inhibitor reaching those points where it is most needed. The combination of small anode and large cathode causes very intense local attack, and the loss of thickness at the pit formed below the blister may be greater than if no inhibitor had been added. Anodic inhibitors are efficient if added in sufficient quantity, but are dangerous if added in a quantity barely enough to stop attack. This presents a difficult problem, since it is almost impossible to define the sufficient quantity. The concentration which would be ample to prevent corrosion at easily accessible parts of a surface may be insufficient at crannies, where replenishment is slow.

The places where intensified attack may occur in a liquid containing barely enough of an anodic inhibitor include the following:

(i) At sensitive points, where the invisible air-formed oxide film on the metal is discontinuous, owing to surface defects or inclusions, or where subsequently formed films tend to rupture spontaneously owing to local internal stresses in the metal, a membranous blister, round or elongated, will probably be formed; when broken open it is likely to reveal a pit.

(ii) At the water-line on a partly immersed plate, there may appear, instead of an ordinary blister, a 'box' of triangular cross-section, its upper side being a curved membrane attached to the meniscus surface. Within the box the metal suffers severe grooving. On steel 0·08 mm. thick and in solutions containing sodium chloride and sodium carbonate in unsuitable proportions,[5] the grooving may develop into perforation along the water-line, within three weeks. The meniscus provides, not only a crevice inaccessible to the replenishment of inhibitor, but a place where the blocking substance may easily adhere to the liquid/gas interface, instead of the liquid/metal interface, and will then fail to form a protective film; there may be other reasons for the specific attack at this level.

(iii) At crevices formed where two steel surfaces come close together, or where a non-metallic substance rests on the steel, the difficulty of replenishment may set up attack. In certain types of cooling plant, debris such as string, cotton waste, or even rust or mill-scale from some other part of the system, may settle on the steel surface and, if the area screened represents only a small fraction of the whole, the dangerous combination of large cathode and small anode may set up intense localized attack.

(iv) In some plants, where the water circulates rapidly along the main channels, there may be side tubes or corners, where conditions are stagnant, which will militate against replenishment.

Synopsis

Many inhibitors, added to water or chloride solution in amounts insufficient to stop attack altogether, produce localized attack, which is more intense than the general corrosion met with in the absence of an inhibitor. Inhibitors which are free from this danger are, in most cases, inefficient. It is believed that the danger is connected with the formation of blister-like membranes over the sensitive points, which prevent the access of the inhibitor to those very points where it is required. By using suitable mixtures of phosphate and chromate (or phosphate and persulphate), so that any substance precipitated will not be ferrous phosphate but ferric phosphate a crystalline non-membranous body), the danger can be avoided. Even if the mixture is added to an amount too small to stop corrosion altogether, no intensified corrosion or pitting is observed.

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* Dr. Palmer is University Lecturer in the Department of Inorganic and Organic Chemistry at the University of Cambridge.

**The range of *p*H at which inhibition occurs may not always correspond to that over which precipitation occurs on addition to ferrous salt solution; probably this is because the *p*H value at a metallic surface differs from that in the body of the liquid. There are certain adsorption inhibitors which act specifically at the anodic areas of an iron specimen, probably by simple attachment to the bare metal, but which do not give a precipitate when added to a ferrous salt solution.

(v) Steel which has become covered with patches of rust through exposure to the atmosphere and which is 'actively' corroding (producing ferrous salts) below the rust, is difficult to deal with by means of inhibitors, since these will often interact with the ferrous salt, forming a membrane over the outer surface of the rust patch, which will prevent the inhibitor soaking in and reaching the metal.

The logical method of dealing with these difficulties appears to be the adoption of an inhibitor or inhibitive mixture chosen to precipitate iron salts in a non-membranous form. It has been suggested that such a plan can, at least, avoid intensification of attack. Roetheli and Cox[6] studied the effect of chromate additions on the corrosion caused by chloride solutions on moving specimens of different metals. Iron and zinc suffered localized attack or pitting if the addition of chromate was insufficient. In the case of lead, the addition of chromate, in quantities insufficient to stop attack completely, produced no pitting. The attack remained general, although the diminution of corrosion was not very marked. This is probably connected with the fact that lead chromate is a substance which is precipitated as a powder, rather than as a membrane. The importance of this factor has perhaps been overlooked, but it appears to possess great possibilities.

Dr. Palmer describes a research in which he uses phosphate and an oxidizing agent in combination, so that any precipitation of iron occurs as ferric phosphate, a non-membranous substance, in the place of ferrous phosphate which forms typical membranes. He has tested these mixtures under numerous conditions—including stagnant and moving water, high and low temperatures—and has also sought to discover whether, when the addition of inhibitor is insufficient to stop attack altogether, the corrosion which still occurs is general or localized, and whether there is risk of dangerous pitting or grooving in the positions mentioned previously. The results have been encouraging, and it seems that mixtures of phosphates and oxidizing agents may fairly be regarded as safe inhibitors, although phosphates alone, which produce typical membranes, are certainly dangerous inhibitors. The mixtures may also be regarded as reasonably efficient, as the concentrations needed to stop attack are lower than those needed with phosphate alone, and all the quantities are fairly low, even in the presence of chlorides—a condition where most inhibitors fail.

If the phosphate and the oxidizing agent are present in the correct ratio, the mixtures seem to represent an inhibitive addition which is both safe and reasonably efficient. Even if the addition made is insufficient to prevent corrosion altogether, there appears to be no intensified attack or pitting. If, however, the proportion of the two constituents is wrong, intense attack becomes possible. As is shown in Dr. Palmer's experiments of Series 20, the removal of phosphate by the calcium present in natural water may bring the ratio to a value consistent with pitting. Probably the removal of the oxidizing agent, e.g., by algae growing in cooling systems, might have a similar unfortunate effect. Furthermore, of the two oxidizing agents hitherto used, chromates must be regarded as toxic, and persulphates are unstable at high temperatures. Thus, it cannot be regarded as certain that the paper provides the final solution of the problem of providing an inhibitive addition which is both safe and efficient; but it is felt that, even if the present mixtures are considered to be unsuitable for certain industrial uses, the research does represent a definite step forward in the development of a satisfactory system of inhibitive-water treatment.

Introduction

WHEN SOLUTIONS of chromic acid, or of alkali dichromate or chromate, are added to excess of a solution of ferrous chloride, the resulting clear dark-brown liquid remains free from precipitate, even after boiling. The addition of any soluble sulfate (*e.g.*, of K, Na, or NH_4) immediately induces a copious brown precipitate. A similar precipitate is, of course, immediately produced if a solution of ferrous sulpate replaces one of ferrous chloride. If, on the contrary, ferrous chloride is added to excess of the chromate oxidizing agent, a dark-brown and gelatinous precipitate forms immediately.

The first product of the interaction is a positively charged sol, probably composed of the mixed hydroxides of iron and chromium, which is stable to singly charged anions, such as Cl^-, but which is readily coagulated and precipitated by doubly charged anions, such as SO_4^{--}, $Cr_2O_7^{--}$ or CrO_4^{--}. Similar phenomena are to be observed when chromate or dichromate is reduced by other agents, such as hydroxylamine hydrochloride.

These facts bear closely on the course of events during the subaqueous corrosion of iron in the presence of chromates or dichromates intended to act as soluble inhibitors. At the 'weak spot' X (Fig. 1), a fairly concentrated solution of ferrous chloride may develop, which, in contact with dilute chromate or dichromate, yields in the first instance the colloidal dispersion described above. Only at some distance from the weak spot, where the concentration of doubly charged anion suffices, is an irregularly shaped membrane of coagulum formed (Fig. 1*a*). This membrane is very probably intrinsically less permeable to $Cr_2O_7^{--}$ or CrO_4^{--} than to Cl^-. Hence the localized corrosion is at most only partially stifled, and the original 'weak spot' tends to enlarge and deepen into a pit, which often assumes a characteristic stellate appearance, owing to the rupture and reformation of the membrane at points on its circumference. The dangerous local corrosion can be ultimately prevented if the disparity in specific permeability is offset by employing a sufficiently high concentration of chromate as inhibitor, but such a method would have only academic interest.

On mixing a solution of a ferrous salt with a solution of potassium dihydrogen phosphate at room temperature, the liquid remains clear and no precipitate is produced, for ferrous acid phosphates are soluble. On adding dichromate to the mixture a precipitate of mixed ferric and chromic phosphates immediately forms, which, when inspected in the microscope, is seen to be crystalline. Indeed the

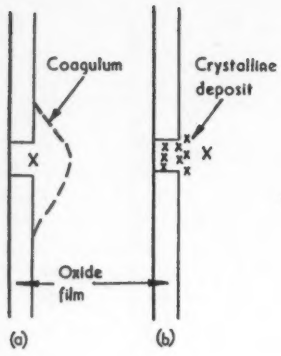

Figure 1—Corrosive and protective action at a 'weak spot' in the oxide film.

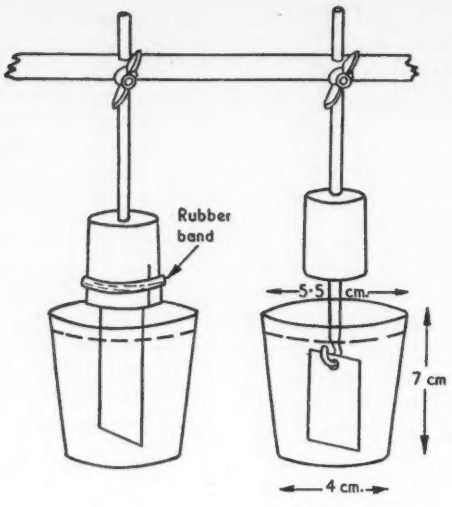

Figure 2—Method of supporting test-pieces.

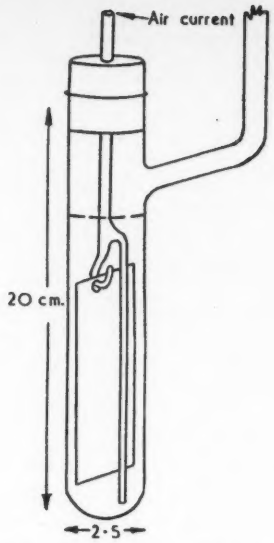

Figure 3—Apparatus for experiments at the boiling-point, with or without air stirring.

whole reaction may be carried out on a slide under the microscope, when it is proved that the precipitate is crystalline from the moment of its formation. If, therefore, the inhibitor contains phosphate in sufficient quantity, as well as dichromate, it may be expected that the harmful membrane will be replaced by a crystalline plug at the mouth of the weak spot. (*See* Fig. 1*b*.) Such a plug will rapidly seal off and repair the weak spot, as before this is accomplished, its material will not specifically antagonize the passage of dichromate ions. The role of the dichromate in such a mixed inhibitor is to ensure that ferric ions are formed as speedily as possible from the first corrosion product, thus guaranteeing a precipitate of crystalline material. Hence, it may be expected that other sufficiently powerful oxidizing agents would, in conjunction with phosphate, exert a similar beneficial action. The work to be described will show that a mixture of potassium persulphate and phosphate inhibits the corrosion of mild steel in chloride solutions at least as effectively as the more familiar dichromate mixture.

Apparatus, Methods, and Materials

For most of the experiments, test-pieces 2 cm. × 7·5 cm. were cut from mild-steel sheet 0·3 mm. thick, which was free from mill-scale, and which had been thoroughly abraded with No. 1 emery cloth. An analysis of this material, supplied through the kindness of Dr. W. E. Hoare, was as follows:

C, %	Si, %	S, %	P, %	Mn, %	Cu, %	Al, %
0·13	0·01	0·061	0·060	0·35	0·08	trace

The specimens were cut and abraded to remove 'raw' edges, and left in a desiccator for at least 24 hr. They were then washed in a stream of carbon tetrachloride immediately before immersion in the corroding solution. In tests with partially immersed pieces, a depth of 4 cm. was usually maintained. For experiments in stagnant solution at room temperatures with partial immersion (in tumbler glasses holding 100 ml.) it was convenient to support each specimen vertically by inserting it into a partially split cork, which was itself carried on a short vertical rod that could be clamped to a long horizontal bar (*see* Fig. 2). Usually, 24 such supports, each with its test-piece, were in use simultaneously. Thorough examination of the test-piece *in situ* during a test was facilitated by the possibility of turning its cork support freely round the vertical rod, and the incidence of light at various angles, indispensable in judging the condition of the surface, was easily secured. For experiments with total immersion in stagnant solution, at room temperature, the cork support was replaced by a hooked glass rod, itself attached to a vertical clamped rod by a small cork, so that rotation was again facilitated. The glass hook was passed through a small hole drilled near the upper edge of the test-piece after cutting. (*See* Fig. 2.)

Experiments were also made under conditions of continuous stirring and aeration by a current of air, and also at temperatures near the normal boiling point of water. For these it was convenient to use closed vessels of the form shown in Fig. 3. The vertical side-tube served, when necessary, not only as a support for the vessel, but also as a condenser. The tubes could be placed in a boiling-water bath in sets of four. In experiments with aeration, air was drawn through the central tube, on which also the specimen was supported by a glass hook. By adjusting the axis of the vessel, if necessary slightly out of the vertical, it was easy to ensure that air bubbles flowed equally over both sides of the test-piece, or alternatively, over one side only. During all series of experiments, under whatever conditions, special care was taken to give identical treatment to each speci-

men, particularly in respect to movement of the specimen, addition of make-up fluid, depth of immersion, and all similar manipulative details.

At the close of a test on abraded pieces any deposit adhering to the specimen was removed by firm treatment with a 'policeman,' and allowed to fall into the liquid from which the specimen was withdrawn. Insoluble matter was then dissolved by adding sufficient hydrochloric acid and boiling. Solutions with surviving dichromate were then cooled, hydrogen peroxide was added, and the liquid again boiled, when dichromate was reduced to the chromic state and excess of peroxide destroyed. In tests where an oxidizing agent was not used, or did not survive, ferrous material in the corrosion product was oxidized by adding hydrogen peroxide to the acid solution, followed by enough aqueous ammonia to precipitate completely all iron as hydroxide, which was then redissolved in acid. In either case total corrosion product was finally estimated by titration with approximately N/20 (standardized) titanous chloride.

Discussion of Results

The first group of experiments, (for details see Section A. of the Appendix) were devised to test the efficiency of the inhibitor mixture when mild steel is exposed, under various conditions, to solutions of potassium chloride in distilled water. In Series 1, 2, and 5, evidence is given that in stagnant chloride solutions as concentrated as 0·2 *M* (14,800 p.p.m.) complete protection is given (at the laboratory temperature) by a mixture containing about 900 p.p.m. of potassium dichromate and 7000 p.p.m. of potassium phosphate, KH_2PO_4, whether the specimen is half immersed or completely immersed in the liquid. In practice there is the probability of the inhibitor mixture becoming temporarily impoverished by extraneous influences. The results of Series 2, 3, and 4 afford some assurance that the immunity gained initially will 'carry over' sufficiently to obviate the onset of any dangerous type of corrosion in any period when the inhibitor becomes too dilute to prevent corrosion entirely. In particular, the results of Series 2 show that if the more vulnerable of the constituents of the inhibitor mixture, the dichromate, decreases from an initial concentration of 900 p.p.m. to 150 p.p.m., a harmless general or distributed type of corrosion supervenes, quite distinct from the dangerous pitting type well known to be induced by insufficient chromate without added phosphate (*e.g., see* Section A., Series 1, experiments 3, 4, and 5). In the absence of extraneous effects the consumption of dichromate is equivalent to the total corrosion (Series 10). Conditions will frequently arise in which the aqueous corroding liquid is in rapid and continuous agitation, but the results of Series 6 (agitation by shaking in closed vessels) and Series 10 (agitation by air current) indicate conclusively that, at the laboratory temperature, the inhibitor mixture is as fully protective under these conditions as in those of stagnant liquids.

In the hope that efficient protective action might be afforded by the dichromate-phosphate mixture, even in hot saline solutions, the experiments in Series 8, 9, and 10 at 90-100° C. were undertaken, and yielded rather puzzling results. When the inhibitor mixture was composed of dichromate and secondary sodium phosphate (Na_2HPO_4), operating in stagnant aqueous potassium chloride (7400 p.p.m.), the protective action was excellent, but if the primary potassium salt, KH_2PO_4, used in all the previous successful experiments, replaced the sodium salt (with consequent fall of *p*H), protection was seriously diminished, and some pitting of the specimens occurred. The experiments in Series 9 proved that the mixture with Na_2HPO_4 was no less satisfactory when the hot liquid was stirred by the passage of an air current, but under these conditions (Series 10) KH_2PO_4 seemed equally effective.

An attempt was made in Series 7 to determine the relative efficiency of primary and secondary phosphate, or, in other words, the effect of variation of *p*H on the protective action of the dichromate-phosphate mixtures. It might have been expected that, as the *p*H rose and dichromate was progressively replaced by chromate, the inhibiting efficiency would fall, for chromate is a less potent oxidizing agent than dichromate, but no evidence was found for any such diminution of efficiency between a *p*H of about 5 and a *p*H of about 12. The experiments were confined to stagnant potassium chloride solutions (7400 p.p.m.) at laboratory temperature.

The theory of the protective action of dichromate-phosphate mixture outlined at the beginning of this paper assigns to the dichromate, as its chief role, an oxidizing action sufficiently rapid to ensure that (crystalline) ferric phosphate is deposited at a weak spot, which is the seat of primary corrosion. The contemporaneous deposition of chromic phosphate is doubtless not unhelpful in healing the weak spot, but it is not an essential feature. Other oxidizing agents of sufficient power might therefore exert, in conjunction with phosphate, protective action comparable with that of dichromate. A development in this direction is most desirable, for the toxic properties of chromates and dichromates could preclude their employment in many conditions of water treatment. The experiments of Series 12, 13, and 14 are devoted to a study of the protective action of potassium persulphate-potassium phosphate mixtures. The use of persulphates must be limited to normal temperature conditions, owing to their instability at higher temperatures. The results in this Section, on the whole, corroborate the theory, and indicate that the use of persulphate-phosphate mixtures would be effective, but they differ in action from dichromate-phosphate mixtures in their greater sensitiveness to *p*H—they are effective only in the range of *p*H 7 to 9. However, there would not necessarily be any real difficulty in maintaining such a limited range in practice, for the phosphate is strongly buffering.

The experiments on dichromate-phosphate mixtures, detailed in Section B., were aimed at testing their efficiency: (*a*) *in natural waters, and* (*b*) in preventing further corrosion on material which had already rusted. Series 15 gives tests in sea water,

Series 16, 17, 18, 20, and 21 give tests under a wide variety of conditions in the hard Cambridge tap water, and Series 19 some tests in the soft Tees Valley tap water. As expected, the concentration of both constituents of the inhibiting mixture may be markedly reduced, because of the relatively small saline content of these liquids. Even in sea water a mixture containing 80 p.p.m. of dichromate with approximately 100 p.p.m. of phosphate suffices, and with the tap waters 50 p.p.m. of dichromate is ample. In hard waters the formation of insoluble calcium phosphate must be allowed for in estimating the amount of phosphate to be employed in the inhibitor (Series 20). The results in Series 17 and 18, at concentrations of inhibitor mixture too low to ensure complete protection, demonstrate again that when corrosion sets in, it remains of a distributed type. The tests on pre-rusted specimens, and on specimens with mill-scale, gave rather erratic results, not easy to generalize, and it cannot be claimed that the inhibitor mixtures operate so effectively in these strenuous conditions as they do on abraded surfaces.

The chart of minimal amounts of inhibitor, shown below, forms an introduction to the results of the tests which are given in the Appendix.

CHART OF MINIMAL AMOUNTS OF INHIBITOR

Reference to Tests	CONDITIONS			Fluid Tested	INHIBITOR, P.P.M.	
	Temperature, °C.	Fluid	Immersion		$K_2Cr_2O_7$	Phosphate
Section A·2, 3, and 5....	Normal	Stagnant	Half	0·20 M Potassium	1000 1500	7000 KH_2PO_4
Section A·7, 8, and 10...	Normal 90-100	Stagnant Stagnant	Half Half or total	0·10 M Potassium Chloride	600	Various mixtures from KH_2PO_4 3500 with NaOH 200, to 9000 of hydrated Na_2HPO_4, giving pH from 6 to 12.
	Normal	Air-stirred		0·10 M Potassium Chloride	500	3500 KH_2PO_4
	90-100	Air-stirred		0·10 M Potassium Chloride	300	3500 KH_2PO_4
	Normal	Air-stirred	(Pre-rusted specimen)	0·10 M Potassium Chloride	300	3500 KH_2PO_4
Section B·17 and 18..... Section B·21.....	Normal 90-100	Stagnant Stagnant	Half Total	Cambridge tap water (hard)	50	100 KH_2PO_4 or 250 hydrated Na_2HPO_4
Section B·19.....	Normal	Stagnant	Half	Tees Valley tap water (soft)	50	As for Cambridge tap water
Section B·20.....	Normal	Aereated		Cambridge tap water	20	80 KH_2PO_4
Section B·15.....	Normal	Stagnant	Half	Sea water	80	200 KH_2PO_4
Section B·22.....	Normal	Stagnant	Half (Pre-rusted specimen)	Cambridge tap water	50	100 KH_2PO_4 or 250 hydrated Na_2HPO_4
	Normal	Stagnant or Areated	Half (Specimen with mill-scale)	Cambridge tap water	300	600 KH_2PO_4

APPENDIX

Data and Experimental Results

SECTION A. LIQUIDS CONTAINING ONLY POTASSIUM CHLORIDE IN ADDITION TO THE INHIBITOR MIXTURE

Potassium Dichromate With Alkali Phosphates as Inhibitor

Series 1. Half Immersed in Stagnant Liquid at Room Temperature.

No.	$K_2Cr_2O_7$, mol./litre	KH_2PO_4, mol./litre	KCl mol./litre	Total Corrosion mg. of Fe/sq.dm./day
1.....	nil	nil	0·10	60
2.....	nil	0·50	0·10	33
3.....	0·005	nil	0·05	8·8
4.....	0·005	nil	0·10	10·7
5.....	0·005	nil	0·20	16·8
6.....	0·005	0·05	0·05	Corrosion below water-line nil
7.....	0·005	0·05	0·10	
8.....	0·005	0·05	0·20	

Conversion to parts per million:
$K_2Cr_2O_7$ 0·005 = 1470 p.p.m.; KH_2PO_4 0·05 = 6800 p.p.m.; KCl 0·05 = 3700 p.p.m; 0·10 = 7400 p.p.m., and 0·20 = 14,800 p.p.m.

Duration of test: 11 days.
Detailed observations after 2 days:
No. 3-5: Coated irregularly with brown, gelatinous deposit, which re-formed when wiped off.
No. 6-8: Pieces bright as at entry.
Final Appearances:
No. 1 and 2: General corrosion.
No. 3 and 4: General corrosion, accompanied by pronounced pits, more numerous on No. 4.
No. 5: General corrosion, with few but deep pits.
No. 6-8: Pieces as before test, except for some local staining.

Series 2. Constant KH_2PO_4 and KCl, but Variation of Dichromate (conditions as in Series 1)

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.	Total Corrosion, mg. of Fe/sq.dm./day
1.....	0·005 (147)	Constant at 0·05 (6800) in all tests	Constant at 0·20 (14,800) in all tests	20
2.....	0·001 (294)			14
3.....	0·002 (588)			13
4.....	0·003 (882)			Very small

Duration of Test: 13 days.
Final Appearances:
No. 1: After removal by gentle abrasion of some dark-coloured incrustation, a stain remained on the piece, but there were no pits.
No. 2 and 3: Some sub-general attack only on one side of each piece.
No. 4: No attack.

Series 3. Effect of Progressive Impoverishment in Dichromate (conditions as in Series 1 and 2)

Three test-pieces were transferred in stages to liquids progressively weaker in dichromate, with KH_2PO_4 constant at 0·05 *M* (6800 p.p.m.), and KCl constant at 0·20 *M* (14,800 p.p.m.).

$K_2Cr_2O_7$, mol./litre and p.p.m.	Total Corrosion, mg. of Fe/specimen
Stage 1 : 3 days 0·005 (1470).....	Nil
Stage 2 : 3 days 0·003 (882).....	Very small
Stage 3 : 13 days 0·001 (294).....	11, 13, 11 avg. 12

Observations:
The pieces seemed unchanged, except for dark stains.

Series 4. Effect of Progressive Impoverishment of both Dichromate and Phosphate (conditions as in Series 3)

	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	Total Corrosion, mg. of Fe/specimen
Stage 1 : 2 days	0·005 (1470)	0·05 (6800)	Nil
Stage 2 : 2 days	0·0025 (735)	0·025 (3400)	Very small
Stage 3 : 8 days	0·001 (294)	0·0125 (1700)	28, 21, 23·5 average 24 (large water-line contribution)

KCl was constant at 0·20 *M* (14,800 p.p.m.) in all stages.

Observations:

All pieces showed local etching, but no pits were discernible.

Series 5. Repetition of Series 1, Except that Specimens were Totally Immersed

Pierced test-pieces, 3·8 cm. × 1·9 cm., were supported loosely on a glass hook vertically and centrally in 100 ml. of liquid (*see* Fig. 2). The top of the piece was approximately 1 cm. under the surface of the liquid, and the bottom was approximately the same distance above the base of the containing vessel. During the test, which lasted 5 weeks, the pieces were shaken from time to time by smartly tapping the glass supports.

No.	$K_2Cr_2O_7$, mol./litre and p.p.m	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.	Total Corrosion mg. of Fe/specimen
1	0·005 (1470)	nil	0·05 (3700)	5·2 } Severe local attack
2	0·005	nil	0·10 (7400)	10 } Severe local attack
3	0·005	nil	0·20 (14,800)	13 } Severe local attack
4	0·005	0·05 (6800)	0·05	Very small
5	0·005	0·05	0·10	Very small
6	0·005	0·05	0·20	Very small

Duration of Test: 5 weeks.
Observations:

No. 1-3: Covered after a short time with a brown, slimy deposit, not readily removed by shaking the piece.

No. 4-6: A small amount of white phosphate at first formed round the suspension hole, but this ceased in 24 hr. No other attack appeared.

During the later part of the test, gas bubbles persistently accumulated on the pieces 1-3. No gas was at any time seen on pieces 4-6.

Final Appearances:

No. 1-3: Severe local attack, with flaking of the metal surface.

No. 4-6: Pieces almost as bright as at the beginning of the test.

Series 6. Preliminary Experiments with Rapidly Moving Liquid

Four test-pieces of steel were each securely and centrally wedged in the cork bungs of wide-mouthed bottles, which contained the liquid for the test. The four bottles were set horizontally in a shaking machine. The planes of two of the test-pieces in each test were horizontal, and those of the other two vertical. Sufficient liquid was present to immerse the test-piece completely when the liquid was at rest and the bottle lying horizontal. At a later stage in the work (*see* Series 9) it was found more convenient to agitate the liquid by means of an air current.

	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.
Test 1	0·003 (882)	0·025 (3400)	0·20 (14,800)
Test 2	0·003	nil	0·20

The bottles were continuously shaken for 3 days, and then remained quiescent, with the pieces totally immersed, for 36 hr. Shaking was resumed for a further 3 days.

Observations:

Test 1: No pits and very slight etching.

Test 2: Shallow pits formed. No observable difference on pieces placed vertically or horizontally.

Series 7. The Protective Effect of Phosphate-Chromate Mixtures in Relation to the pH of the Liquid

The specimens were half immersed in stagnant liquid at room temperature. The $K_2Cr_2O_7$ was constant at 0·002 mol./litre (588 p.p.m.), and the KCl was constant at 0·10 mol./litre (7400 p.p.m.).

No.	KH_2PO_4, mol./litre	NaOH, mol./litre	Na_2HPO_4, mol./litre	Approx. pH	Total Corrosion, mg. of Fe
0	nil	nil	nil	....	53·5
1	0·025	nil	nil	4·7	16·4
2	0·025	0·005	nil	6·2	Total for all pieces 14·5 Average 1·8
3	0·025	0·010	nil	6·7	
4	0·025	0·015	nil	7·0	
5	0·025	0·020	nil	7·4	
6	0·025	0·0225	nil	7·7	
7	nil	nil	0·025	8·3	
8	nil	0·002	0·025	11·0	
9	nil	0·005	0·025	11·8	
10	nil	0·005	nil	....	8·3

Conversion to parts per million:

KH_2PO_4 0·025 mol./litre = 3400 p.p.m.

Na_2HPO_4 0·025 mol./litre = 8950 p.p.m. hydrate $Na_2HPO_4 12H_2O$.

NaOH:

mol./litre	0·005	0·010	0·015	0·020	0·0225
p.p.m.	200	400	600	800	900

Duration of Test: 27 days.
Observations:

No. 0 ($K_2Cr_2O_7$ sole inhibitor). This specimen suffered very severe continuous attack at, and just below, the water line. At the close of the test, pits had appeared over all the immersed portion, from which loose corrosion product fell continuously.

No. 10 ($K_2Cr_2O_7$ with KH_2PO_4). Nearly all the attack on this specimen occurred at the water-line.

No. 2-9. None of these specimens suffered attack on the immersed portion, and at the water-line the corrosion was absent or very slight. On removal at the end of the test all these specimens showed resplendent interference colours, the varying tints of which indicated a surface film of thickness steadily increasing from *p*H 6 to *p*H 12.

No. 10 (K_2CrO_4 sole inhibitor). This specimen was attacked locally, at the water-line, and at the base of the immersed portion.

Interference colours on specimens of Series 7:

No.	Colour	pH
2	Faint blue	6·2
3	Faint yellowish blue	6·7
4	Faint yellow	7·0
5	Orange	7·4
6	Orange, purple	7·7
7	Green, orange	8·3
8	Green, purple	11·0
9	Dull green, red	11·8

Series 8. The Action of Phosphate-Chromate Mixtures in Hot Stagnant Chloride Solution

The closed vessels shown in Fig. 3 were used in this series. Fifty ml. of liquid were used for half-immersed specimens, and 60 ml. for totally immersed specimens. The temperature was between 90 and 100° C. Potassium chloride was constant at 0·10 mol./litre (7400 p.p.m.).

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	Na_2HPO_4 mol./litre and p.p.m.	Immersion	Area Exposed	Duration, Days
A1, A2	0·001 (294)	0·025 (3400)	.....	Half	9·5 cm.²	7
B1, B2	0·001 (294)	0·025 (3400)	.....	Total	11·4 cm.²	7
A3, A4	0·002 (588)	.....	0·025 (8950, $12H_2O$)	Half	9·5 cm.²	11
B3, B4	0·002 (588)	.....	0·025 (8950, $12H_2O$)	Total	11·4 cm.²	11

Final Appearances:

Specimens *A*1 and *A*2 were somewhat discoloured below the water-line, and there was considerable unavoidable rusting above the water-line. There was local etching and some pitting on the immersed portion. Specimens

*B*1 and *B*2 showed less-marked pitting and etching than *A*1 and *A*2. The total corrosion was slight in both sets of specimens.

Specimens *A*3 and *A*4 showed brilliant temper colours, of high order. Water-line attack was very slight, and the very few small pits were discernible only by very careful inspection.

Specimens *B*3 and *B*4 showed first-order blue colours, and no attack at any point.

Series 9. Air Stirring with Intermittent Quiescent Periods

In this series, and those subsequently in which air stirring was operated, the closed tubes of Fig. 3 were used, the central tube admitting the air current. Evaporation was minimized by drawing the air first through a water bubbler held in the water-bath.

The liquid contained the same constituents as for the tests *B*3 and *B*4 in Series 8, *viz.*: $K_2Cr_2O_7$ 0·002 mol./litre (588 p.p.m.); Na_2HPO_4, 0·025 mol./litre (8950 p.p.m., $12H_2O$); and KCl, 0·10 mol./litre (7400 p.p.m.). As in the tests in Series 8 the pieces were totally immersed (area exposed 11·4 cm.²).

Air stirring was maintained for 5 days, followed by a quiescent interval of 2 days, which in turn was succeeded by 3 days' stirring. The total duration was 10 days, at a temperature of 90-100° C. throughout.

Final Appearances:

All four specimens showed high-order interference colours, and very slight local etching, but no pits.

Series 10. Continuous Air Stirring at Room Temperature

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.
1	0·0005 (147)	Constant at 0·025 (3400)	Constant at 0·10 (7400)
2	0·001 (294)		
3	0·0015 (441)		
4	0·002 (588)		

Area of Specimen Exposed: 11·4 cm.²
Duration of Test: 12 days.

Final Appearances:

No. 1 and 2: Some slight local etching.

No. 3 and 4: No attack visible under the lens, but the estimate of iron in the liquid (*see* the following data) indicates very slight general corrosion.

The use of low concentrations of dichromate in this series offered an opportunity of directly testing whether the loss of dichromate during the test corresponded with the actual amount of corrosion.

No.	1	2	3	4
Total $K_2Cr_2O_7$ in original liquid	8·85	16·5	26·85	36·6
$K_2Cr_2O_7$ recovered	5·3	13·1	23·3	33·0
$K_2Cr_2O_7$ consumed	3·55	3·4	3·55	3·6
Total Corrosion (mg. of Fe)	2·0	4·2	3·5	2·8
$K_2Cr_2O_7$ equivalent to corrosion	1·8	3·75	3·15	2·50

$K_2Cr_2O_7$ is expressed in terms of ml. of N/50 sodium thiosulphate. The amount consumed is estimated by difference.

The losses of dichromate are seen to correspond satisfactorily with the total corrosion.

Continuous Air Stirring at 90-100° C

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.
1	nil	nil	Constant at 0·10 (7400)
2	0·005 (1470)	nil	
3	0·0025 (735)	0 025 (3400)	
4	0·005 (1470)	0 05 (6800)	

Area of Specimen Exposed: 8·3 cm.²
Duration of Test: 7 days.
Final Appearances:

No. 1: Very severe corrosion (total amount 324 mg. of Fe).

No. 2: Sparse localized attack, with adherent deposit.

No. 3 and 4: No attack, but pieces all displayed brilliant interference colours.

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.
1	0·0005 (147)	Constant at 0·025 (3400)	Constant at 0·10 (7400)
2	0·001 (294)		
3	0·0015 (441)		
4	0·002 (588)		

Final Appearances:

Even with the lowered concentration of dichromate, no specimen suffered appreciable attack, but all showed the brilliant colours mentioned previously.

Series 11. The Protection Afforded by Phosphate-Chromate Mixtures to Pre-Corroded Steel in Chloride Solutions

(1) Three specimens abraded in the usual way, each having an area of 11·4 cm.,² were totally immersed for 2 days at room temperature in 100 ml. of *M*/10 potassium chloride solution containing the following quantities of sodium carbonate. This treatment gave local corrosion as follows:

1. 0·05 g. of Na_2CO_3 : Severe attack over approximately two-thirds of the area
2. 0·10 g. of Na_2CO_3 : Severe corrosion over approximately one-half of the area.
3. 0·20 g. of Na_2CO_3 : Moderate corrosion over less than one-tenth of the area.

After the treatment described, the specimens were removed, wiped carefully with a 'policeman,' and dried in a desiccator. Each was then totally immersed in the mixture:

KCl 0·10 mol./litre (7400 p.p.m.); $K_2Cr_2O_7$ 0·001 mol./litre (294 p.p.m.); KH_2PO_4 0·025 mol./litre (3400 p.p.m.).

The liquids were stirred by a vigorous air current at room temperature for 4 days.

Total corrosion of the specimens was as follows:

1. 3·65 mg. of Fe. 2. 3·45 mg. of Fe. 3. 2·60 mg. of Fe

All specimens showed first-order blue on the portions remaining intact after the preliminary treatment, but apart from this, the final appearance of the specimens did not differ from their appearance after the immersion in sodium carbonate mixture.

The total corrosion was small and bore no relation to the area initially corroded. It appears, therefore, that all parts of the specimen received full protection.

(2) Loose rust from 6 specimens (each having an area of 8·25 cm.²), which had been severely rusted by long exposure to laboratory air, was removed by a wire brush. The specimens were then degreased by suspension in the vapour of carbon tetrachloride boiling under reflux, to ensure complete removal of grease from pits. Each specimen was then immersed in the phosphate-dichromate-chloride mixture described in the first experiment. The liquids were kept stagnant at room temperature. A flocculent, very loose deposit of ferric phosphate, which formed immediately on immersion and for some time afterwards, was shaken off, as it was produced, by tapping the support of the specimen. After immersion for 3 hr. the liquid was replaced by a fresh solution of the original composition. Another similar replacement was made after a further immersion period of 24 hr. The specimens were finally left immersed in the same solution for 13 days. The formation of loose deposit ceased after 3 hr. from initial immersion.

Corrosion during first 3 hr., mg. of Fe:

No.	1	2	3	4	5	6
	1·4	1·5	1·0	1·5	0·65	1·5

Corrosion during next 24 hr., mg. of Fe:

Total for all specimens	9·1
Average per specimen	1·5

Corrosion during final 13 days, mg. of Fe:

Total for all specimens	11·6
Average per specimen	1·9

Practically complete protection was given after the first few hours. Comparison under microscopic inspection of specimens in their final state with others in the initial state, revealed no apparent change in appearance, no deepening of pits, or removal of scale.

For further tests on rusted specimens, *see* Section B, Series 22.

Potassium Persulphate ($K_2S_2O_8$) with Alkali Phosphates as Inhibitor

Series 12. Half Immersed in Stagnant Liquid at Room Temperature

No.	$K_2S_2O_8$, mol./litre	KH_2P_4O, mol./litre	Na_2HPO, mol./litre	KCl, mol./litre
1.....	0·0029	0·005	.....	Constant at 0·10
2.....	0·0058	0·05	.....	
3.....	0·0144	0·05	.....	
4.....	0·0029	0·025	0·025	
5.....	0·0058	0·025	0·025	
6.....	0·0144	0·025	0·025	

Conversion to parts per million:

$K_2S_2O_8$:	mol./litre	0·0029	0·0058	0·0144
	p.p.m.	788	1566	3880

KH_2PO_4 0·05 mol./litre (6800 p.p.m.)
Na_2HPO_4 0·025 mol./litre (8950 p.p.m. hydrate $12H_2O$).
Duration of Test: 12 days.

The equivalent oxidizing capacity of 0·0029 mol./litre of $K_2S_2O_8$ is 0·0010 mol./litre (294 p.p.m.) of $K_2Cr_2O_7$. The initial *p*H of specimens 1-3 is 4·7, and of specimens 4-6, 6·8, but as persulphate yields free sulphuric acid on decomposition, this *p*H will diminish if corrosion sets in.

Observations:
No. 1-3: Rapid general corrosion persisted from the time of immersion.
No. 4-6: All unattacked, but exhibited brilliant temper colours.

Series 13. Half Immersed in Stagnant Liquid at Room Temperature

No.	$K_2S_2O_8$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	NaOH, mol./litre and p.p.m.	KCl, mol./litre and p.p.m.	pH (Initial)
1.....		nil	nil		....
2.....		0·025	nil		4·7
3.....		0·025	0·005		6·2
4.....	Constant	0·025	0·010	Constant	6·7
5.....	at	0·025	0·015	at	7·0
6.....	0·005	0·025	0·20	0·10	7·4
7.....	(1350)	0·025	0·0225	(7400)	7·7
8.....		0·025	0·025		....
9.....		nil	0·005		....

Condition after 24 hr.: Liquids 1-4 were replaced by a fresh supply of the original composition. Any deposit on the pieces was gently detached, and the solid received in the removed liquid. Attack was at once resumed after the replacement. The following is an analysis of liquids and deposits removed from No. 1-4 after 24 hr.:

No.	1	2	3	4
$K_2S_2O_8$ surviving, %	nil	nil	25	45
Total corrosion, mg. of Fe	34·2 (20·6 as Fe^{++})	35·1	18·9	8·8

Condition after 6 days: Normal chloride corrosion was continuing on No. 1 and 9 after exhaustion of persulphate. Liquids and deposits from No. 2-4, inclusive, were removed. The fresh liquids had the original amounts of chloride and phosphate, but the persulphate was omitted, with the object of testing whether these pieces had gained any protection by previous treatment.

At this stage, No. 5, 6, and 7 (*p*H 7·0 to 7·7) were still unblemished, excepting for a feeble water-line attack decreasing in the order 5, 6, 7.

The following is an analysis of liquids and deposits removed from No. 2-4 after 6 days:

No.	2	3	4
$K_2S_2O_8$ surviving, % ...	nil	nil	27
Total corrosion, mg of Fe	61	48·5	21·5
Corrosion per day, mg. of Fe	10·1	8·1	3·6

Condition after 14 days: Attack was persisting in No. 2-4, which by this time lacked persulphate. No. 5, 6, 7, and 8, which had been immersed in the same solutions from the start, were removed after a totalof 11 days.

The following analysis of liquids and deposits from No. 5, 6, 7, and 8 was made after 11 days' continuous test in the same solutions:

No.	5	6	7	8
$K_2S_2O_8$ surviving, %	64	82	67	40
Total corrosion, mg. of Fe	8·0	2·4	1·9	6·2
Corrosion per day, mg. of Fe	0·73	0·2	0·2	0·55

Summarized Results of Series 13:

No.	1 May	Mean Corrosion Rate mg. of Fe/day 6 Days	7 Days	Total Days	Corrosion for Whole Period	*p*H
1....	34·2 (nil)*		7·9	14	136	($K_2S_2O_8$ and KCl)
2....	35·1 (nil)	10·0 (nil)	3·3†	14	119	4·7
3....	18·9 (25%)	9·1 (nil)	8·4†	14	76	6·2
4....	8·8 (45%)	3·9 (27%)	11·6†	14	42	6·7
5....	(no	0·73 (64%)		11	8·0	7·0
6....	change	0·2 (82%)		11	2·4	7·4
7....	of	0·2 (67%)		11	1·9	7·7
8....	liquid)	0·55 (50%)		11	6·2	(alkaline phosphate)
9....	do.	8·5 (nil)		14	118	(Free NaOH)

* Persulphate surviving in parentheses.
† No persulphate present in this interval.

Series 14. Persulphate-Phosphate Mixtures in Solution of High pH (conditions as in Series 1 and 2)

No.	Na_2HPO_4	NaOH	Approx. *p*H	Total Corrosion, mg of Fe	Corrosion per Day, mg. of Fe
1.....	0·025	nil	10·0	11·4	1·9
2.....	0·025	0·002	11·0	30·0	5·0
3.....	0·025	0·005	11·8	106·0	18·0
4.....	0·025	0·100	12·3	105·0	18·0

$K_2S_2O_8$ remained constant at 0·005 mol./litre.
KCl remained constant at 0·10 mol./litre.

Duration of Test: 6 days.

Observations: Localized adherent deposits of white ferric phosphate developed on all pieces soon after immersion, the attacked areas lying mainly at, or just below, the water-line. The pieces remained bright between the regions of deposit.

At the close of the test the areas covered by adherent de posit had slightly increased, but no attack occurred at intermediate regions.

SECTION B. POTASSIUM DICHROMATE-ALKALI PHOSPHATE MIXTURES AS INHIBITORS IN NATURAL WATERS

Series 15. Tests in Sea Water*

Tests were made with abraded specimens, as in previous series. The pieces were half immersed in stagnant liquid at room temperature.

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.
1.....	nil	nil
2.....	0·00025 (73·5)	0·00125 (170)
3.....	0·0005 (147)	0·0025 (340)
4.....	0·00075 (220)	0·00375 (510)

Duration of Test: 7 weeks.

Observations: Very heavy general corrosion on No. 1, no attack below water-line on Nos. 2, 3, or 4.

There follows a number of tests made on two typical town water supplies: (i) Cambridge town water, very hard, as raw water, but softened by a base-exchange process to a moderate degree of hardness before supply to consumers; this water gave 296 p.p.m. of total solids, and 31 p.p.m. of chloride (as NaCl); (ii) Tees Valley water,** an example of a very soft water, which gave 80 p.p.m. of total solids, and 13.6 p.p.m. of chloride (as NaCl).

* Supplied from Portsmouth through the kindness of Dr. L. Kenworthy.

** Supplied through the kindness of Dr. W. D. Clark.

Series 16. Cambridge Tap Water, General Survey in Relation to *p*H

Tests were made with abraded specimens which were half immersed in stagnant solutions at room temperature. The area immersed was 8·5 cm.²

No.	$K_2Cr_2O_7$, mol./litre and p.p.m.	KH_2PO_4, mol./litre and p.p.m.	NaOH, mol./litre and p.p.m.	*p*H
1	Constant at 0·001 (294)	Constant at 0·01 (1360)	nil	4·7
2			0·001 (40)	....
3			0·002 (80)	6·2
4			0·004 (160)	6·7
5			0·006 (240)	7·0
6	0·0002 (59)	Constant at 0·01 (1360)	Constant at 0·002 (80)	Constant at 6·2
7	0·0004 (118)			
8	0·0006 (177)			
9	0·0008 (236)			

Duration of Tests: 28 weeks.

Observations: All pieces were intact below the water-line, except No. 6, which showed one shallow pit.

Series 17. Cambridge Tap Water. Minimal Amounts for Protection at Normal Temperatures (conditions as in Series 16)

(1) *Tests made in mixtures with KH_2PO_4:*

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	nil	nil	112
2	5	10	94
3	10	20	103
4	20	40	30·5
5	50	100	9·1
6	100	200	0·95

Duration of Test: 4 weeks.

Observations: No. 1-4 showed quite general corrosion; no pitting was detected.

No. 5 and 6 remained bright and completely unblemished below the water-line. The 9·1 mg. of corrosion on No. 5 took place entirely at the water-line.

(2) *Tests made in mixtures with Na_2HPO_4:*

No.	$K_2Cr_2O_7$, p.p.m.	Na_2HPO_4 12 H_2O, p.p.m.	Total Corrosion, mg. of Fe
1	5	25	108
2	10	50	103
3	20	100	41
4	50	250	2

Duration of Test: 4 weeks.

Final Appearances: No. 1, 2, and 3 showed quite general corrosion without any pitting. No. 4 was unattacked at any point.

Series 18. Cambridge Tap Water. Further Tests at or below Minimal Concentrations of Inhibitor (conditions as in Series 15-17)

Test (1). *Duration:* 6 weeks.

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	Constant at 20	nil	91
2		20	78
3		40	13
4		60	25

Test (2). *Duration:* 6 weeks.

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	Constant at 50	nil	9·1
2		20	8·2
3		40	4·1
4		60	16·1

Observations: In Test (1) No. 1 and 2 showed general corrosion, and corrosion in No. 3 and 4 was mostly confined to the water-line.

In Test (2) localized attack occurred on No. 1 only.

Series 19. Tees Valley Tap Water

Tests were made with abraded specimens, half immersed in stagnant fluid, at normal temperature.

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	nil	nil	129
2	5	10	113
3	10	20	93·5
4	20	40	54
5	50	100	6·2
6	100	200	3·0

Duration of Test: 5 weeks.

Observations: No. 1-4 showed general corrosion without pitting. No. 5 and 6 both showed interference colours, but only the slightest attack.

Series 20. Cambridge Tap Water

Tests were made with abraded specimens, totally immersed in fluids vigorously aerated by air current, at room temperature.

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	20	20	458
2	20	40	nil
3	20	nil	364
4	nil	nil	620

Duration of Test: 3 weeks.

Observations: No. 1 showed sub-general attack and No. 4 general corrosion. No. 3 was very severely pitted, and the attack extremely localized.

Four specimens were treated under the conditions of the previous test with the favourable mixture $K_2Cr_2O_7$ (20 p.p.m.) with KH_2PO_4 (40 p.p.m.). (No. 2 of Series 20.) In the course of 3 weeks' test, three of the specimens underwent severe local corrosion, with pitting, but one was almost without attack.

The key to this capricious behaviour was found when four more specimens were treated, as previously, with the mixture of 20 p.p.m. of $K_2Cr_2O_7$ and 80 p.p.m. of KH_2PO_4, *i.e.*, with a doubled amount of phosphate. After three weeks, each of these last specimens had precisely the appearance it had at the beginning of the test, and there was no trace of corrosion at any point. A precipitate of calcium phosphate was observed to form at different times in each case. The immediate product of the action of KH_2PO_4 on aqueous calcium salts would be the soluble $CaHPO_4$. This acid salt is not very stable, and there can be little doubt that the violent agitation of the liquid in these tests caused a precipitation of normal calcium phosphate after unpredictable intervals. In the Cambridge hard water there would be enough soluble calcium salt to decrease the amount of phosphate below safe levels.

Series 21. Cambridge Tap Water

Tests were made on abraded specimens under stagnant conditions at 90-100° C. The pieces were totally immersed.

(1)

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Total Corrosion mg. of Fe
1	10	20	99·2
2	20	40	103
3	50	100	0·7
4	100	200	0·5

Duration of Test: 5 weeks.

Observations: On No. 1 and 2 corrosion was localized to etched areas. No. 3 and 4 had localized black staining, but no pits.

(2) Four specimens totally immersed in water with $K_2Cr_2O_7$ (20 p.p.m.) and KH_2PO_4 (40 p.p.m.) for 18 days at 90-100° C., suffered severe etching.

Similar results were obtained when the phosphate was raised to 80 p.p.m. or replaced by equivalent Na_2HPO_4.

With $K_2Cr_2O_7$ raised to 40 p.p.m., the corrosion (from appearance only) was much reduced, but still considerable.

(3)

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	$Na_2HPO_4 12\ H_2O$, p.p.m.
1	50	100	....
2	100	200	....
3	50	....	200
4	100	....	400

Duration of Test: 3 weeks.

Observations: No corrosion took place on No. 1 and 2 or on No. 4. Some localized attack was seen on No. 3.

Series 22. Pre-Rusted Specimens in Dichromate-Phosphate Mixtures

The final series was designed to test the efficiency of dichromate-phosphate mixtures in protecting pre-rusted or mill-scaled specimens from further attack. Preliminary experiments had given encouraging results (*see* Section A., Series 11).

The pieces (6.4 cm. × 2.0 cm.) for the test on rusted material had been exposed to the open air on the laboratory roof for some months, and were immersed in Cambridge tap water containing inhibitor immediately on removal from the exposed position. They were cut from mild steel, of 1.4 mm. thickness, and of the following analysis:

C, 0.13%; Si, trace; S, 0.030%; P, 0.017%, and Mn, 0.39%.

Severely Rusted before Test

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Na_2HPO_4 12 H_2O, p.p.m.	Total Corrosion, mg. of Fe
1	50	nil	nil	236
2	100	nil	nil	252
3	300	nil	nil	9·2
4	600	nil	nil	2·3
5	50	100	....	2·8
6	100	200	....	6·0
7	300	600	....	2·3

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Na_2HPO_4, 12 H_2O, p.p.m.	Total Corrosion, mg. of Fe
8	600	1200	....	28
9	50	....	250	4·8
10	100	....	500	13·6
11	300	....	1500	1·6
12	600	....	3000	16·2

Duration of Test: 3 months.

Total corrosion represents the amount of material which had fallen spontaneously from each piece during the test. When protection was successful, and the amount of corrosion small, the rust of the preliminary exposure remained intact with the piece during the test, and was withdrawn with it at the end.

Mill-Scale Intact on the Faces, but not Rusted

No.	$K_2Cr_2O_7$, p.p.m.	KH_2PO_4, p.p.m.	Na_2HPO_4, 12 H_2O, p.p.m.	Total Corrosion, mg. of Fe
1	nil	nil	nil	315
2	50	nil	nil	333
3	100	nil	nil	345
4	300	nil	nil	198
5	600	nil	nil	12·2
6	50	100	....	194
7	100	200	....	265
8	300	600	....	6·0
9	600	1200	....	6·7
10	50	....	250	190
11	100	....	500	224
12	300	....	1500	5·8
13	600	....	3000	1·5

Duration of Test: 3 months. Conditions similar to those for the pre-rusted specimens.

Observations: The original mill-scale was intact on No. 8, 9, 12, and 13.

Mill-Scale Intact on the Faces, Totally Immersed in Cambridge Tap Water Containing Inhibitor, Stirred by a Vigorous Air Current (cf. Section B, Series 20)

No.	$K_2Cr_2O_7$, p.p.m	KH_2PO_4, p.p.m.	Final Condition
1	50	100	Very severe general corrosion
2	100	200	As for No. 1
3	300	600	Mill-scale intact
4	600	1200	Mill-scale intact

Acknowledgments

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Internal and External Corrosion Experience In Shell's Products Pipe Lines*

By S. S. SMITH, W. J. CURRY and E. H. RUSH

Internal Corrosion

IN VIEW of the operating difficulties other companies had experienced with internal scale, the author's company invited Dr. Aaron Wachter of Shell Development Company at the start of its products line operation in 1938 to investigate the possibilities of prevention of internal corrosion. Dr. Wachter's studies took the form of laboratory experiments to develop an internal corrosion inhibitor, and in the latter part of 1939 he reported his recommendations that an aqueous solution of alkaline sodium nitrite be injected as a corrosion inhibitor of the water phase of the products pipe line.

The injection of sodium nitrite was begun in the latter part of 1939 in very small quantities at the origin point only of the East Line. Then the average "C" factors of this Line were about 138, a fall of approximately 13 points since the start of operation in 1938. The first year's injection gave very moderate increases in "C" factors, as depicted in Figure 1. Therefore, in the latter part of 1940 the injection rates were increased sufficiently to maintain a one to two percent concentration of sodium nitrite in the effluent water from the pipe line. During 1941 the East Line "C" factors improved to the figure of 152 and, as shown on Figure No. 1, have continued to steadily approach an apparent flat level of about 157-158.

In 1940 the North Line operation was started, this line being a readapted crude line which had been in service since 1927. The average "C" factors at the time of conversion were 148, and they fell during the first few months of operation and before injection of sodium nitrite to a figure of 142. After start of sodium nitrite treatment, these factors increased rapidly over the first year to a figure of 155 and steadily improved until 1948, at which time 70 miles of loops were put into service. These loops had been in use since 1940 for seasonal storage of product only and were badly scaled. As a result, the average "C" factors fell about two points, but at the present writing, are again moving upward.

When the value of nitrite in this service had been adequately demonstrated its use was licensed for use under the trade name of "SCIP" in other companies' products pipe lines. The results in all cases have been paralll to those experienced by the author's company except in one or two isolated instances where corrosion had progressed sufficiently to cause severe pitting in the pipe walls. Where heavy pitting exists, the disturbance to flow is sufficient to lower the "C" factors slightly, although in all instances reported capacities have been raised at least 10 percent.

General experience indicates that unless some means of preventing corrosion is available, "C" factors cannot be maintained much above 130 by mechanical scraping. Ancillary factors that derive from inhibition, are the prevention of scale formation with its attendant destruction of mechanical equipment such as meters, pumps, etc., and the reduced difficulty with water haze in fuel oils, which is aggravated when scale is present. Scraping is necessary during the early part of inhibition to move the scale which loosens along the wall of the pipe, but once the lines are cleaned no further scraping is necessary, and the author's company now only scrapes to remove condensate water which comes out of solution

★A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

SYDNEY S. SMITH, manager of Products Pipe Line Dept., Shell Oil Co., has been with Shell since 1924. He holds a BA from Marietta College, with majors in mathematics and physics. Recently concerned with operation and maintenance of products pipe lines, including the development of improved equipment and corrosion control, he formerly pioneered in development of methods for stabilizer control and recovery of volatile fractions and conversion to high octane fuels by synthetic methods. He was awarded a Presidential Medal for Merit for service to the United States in development of portable military pipe lines. He also has won many first prizes for his photographic work.

E. H. RUSH—Joined Shell Oil Company in 1934 as an engineer in construction and maintenance in various locations throughout the company's operations. In 1944 he entered corrosion mitigation experimental work at the company's Wood River East Chicago products pipe line. Since 1948 he has been in charge of all external corrosion activities in the Products Pipe Line Department. He received his BS in engineering from the University of Kansas in 1929.

W. J. CURRY, chief dispatcher for the Products Pipe Line Department of Shell Oil Company, formerly was chief chemist for the department and was concerned with line operation problems, product specifications and corrosion problems incident to products line maintenance and operation. He has a degree in Petroleum Engineering from Colorado School of Mines and has been in Shell's employ since 1928 in the Manufacturing and Products Pipe Line Departments.

Abstract

The paper is in two sections. The first section summarizes ten years of experience on two product lines operated by Shell Oil Company using alkaline aqueous solution of sodium nitrite as an internal corrosion inhibitor. Figures show the short and long time effect of nitrite inhibition, and reduction of cost by elimination of scraper operation and hay tank and strainer operation is discussed. This section includes a generalized statement of increase of capacity which can be expected from sodium nitrite inhibition.

The second section discusses the use of magnesium anodes as an external corrosion preventive on Shell's products pipe line from Wood River to Chicago. The line is now 26 years old and was 21 years old with a moderately high leak frequency when anode installations were instituted. In order to analyze the effects of anode installations, pilot plant experiments were conducted, and the paper reports these pilot plant experiments and their results and the conclusions drawn therefrom. Included in this section of the paper are several sets of field tests conducted before anodes were installed, after anodes were installed, and over several years of life of anodes. Pictures and drawings support the conclusions drawn from pilot plant experiments, and results of field tests and experience during the five years of experimental work on the line are summarized. The conclusions drawn from this section of the report are that proper field testing and installation of magnesium anodes can control destructive corrosion sufficiently to extend the useful life of uncoated pipe lines to approximately double their unprotected life.

in the products due to decreases in line temperature, compared to refinery tanks. Therefore, an additional benefit is the elimination of the cost of mechanical scraping, which of itself is sufficient to pay for the cost of chemicals involved in the process. Many sample tabs have been cut out from the pipe lines, and invariably they are clean, gray steel without even a surface bloom of corrosion.

The original method of inhibiting lines was either by pump or gravity injection of aqueous solution of nitrite and caustic at several points along each line. In recent years it has been found advantageous to inject aqueous solution only at the first station on the line, after which additional injections at approximately 100-mile intervals are made by simply dropping in dry nitrite and soda ash through a double valve standpipe. In this case the nitrite and soda ash are selectively dissolved by the water in the line and inhibition is completely effective. This method of injection is, of course, much less time-consuming and requires no proportioning addition, simply requiring that some quantity of nitrite be dropped in the line daily.

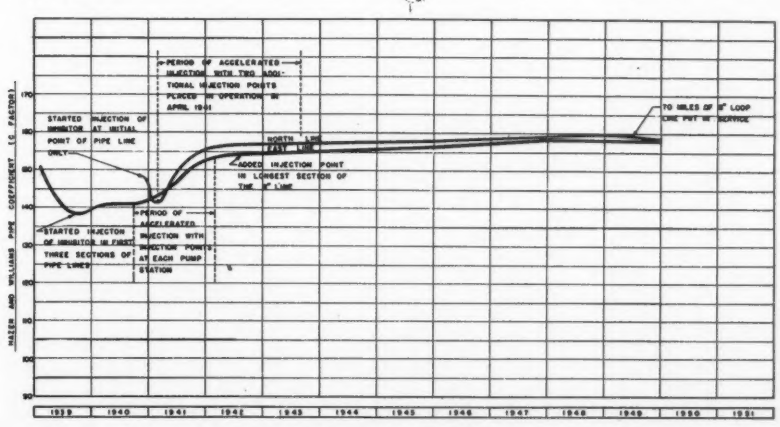

Figure 1—Results of inhibitor treatment of products pipe lines.

Control of inhibitor dosage is determined by occasional analysis of effluent water at the end of the line to determine nitrite content, and as long as this figure remains at approximately 1 percent in the aqueous phase, complete protection is achieved. After the first stages of scale removal dosage remains fairly constant.

The economic benefits of completely effective inhibition can be stated as follows:

An average 15 percent increase of line efficiency can be expected from an inhibited over an uninhibited line with resultant savings in pumping cost or increase of capacity, whichever is more desirable. The cost of scraper runs can be eliminated after the first year or so, or if the line is inhibited immediately after construction the cost of scraper runs can be completely eliminated. Erosion and wear of pump and meter and valve parts is greatly decreased, and repair charges due to these causes commensurately reduced.

In construction of new lines, the capital cost for hay tanks, strainers, filters, etc., can be eliminated with their continued expense for labor and materials. Parenthetically, on the line, the cost of licenses and chemicals was calculated to be completely repaid by the gain of two Hazen & Williams "C" factor points, the other 15 or 20 points being net gain for the user. This summation of results of internal inhibition is intentionally short, and the interested reader can find more complete data in the papers enumerated in the bibliography of this article.

External Corrosion

The author's company operates two eight-inch pipe lines, one extending from Wood River to Chicago, which is called the North Line, and one to Lima and Columbus, which is called the East Line. The East Line was laid in 1938 without coatings except at river crossings, and during and after laying, the usual line current, pipe-to-soil potential, and soil resistivity measurements were made along the line. From these measurements suspected danger points for external corrosion were determined and in subsequent years many of these lines have been coated, cased or cathodically protected. In 12 years of operation one leak has occurred in an extremely localized hot spot overlooked in the original surveys. During inspection or service work on the line pit depths have not been found to exceed 50 percent penetration. In recent years the protective methods have been augmented by fairly large-scale installations of magnesium anodes, but since the line is comparatively young with no leak experience, there is nothing of particular interest in respect to this job for this paper.

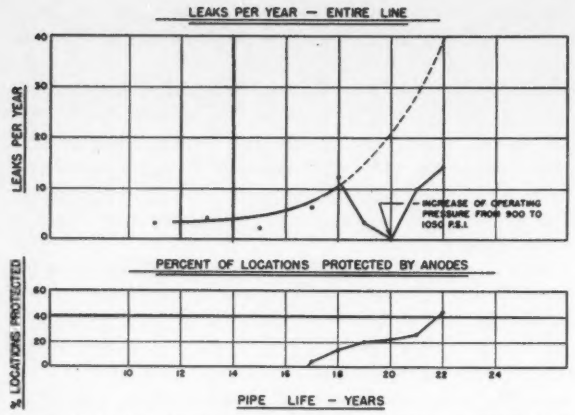

Figure 2—Leak frequency and percent of locations protected for entire line.

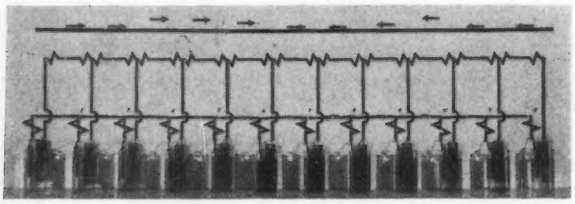

Figure 3—Cell arrangement and electrical circuit used in laboratory experiments. No protection was used in this test.

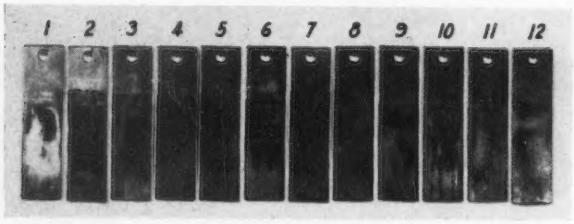

Figure 4—Plates after test shown in Figure 3.

The line from Wood River to Chicago, however, was laid in 1927 and transported crude oil until 1940, when it was converted to a products line. The first leak due to corrosion occurred in June of 1934, in the seventh year of pipe line life.

By 1940, when converted to a products line, leak frequency had progressed to eight actual leaks, and with the usual logarithmic method of plotting, the leak frequency curve was at seven leaks per year. Up to 1945 the line was not considered in bad enough condition to merit reconditioning, and repairs and replacements were made as leaks occurred or inspection indicated. The leak frequency by 1945 had reached a plotted level of 11 leaks per annum.

In 1944 the installation of magnesium anodes was begun, confining original installations mainly to road crossings. The leak frequency experience up to that time indicated that the most serious corrosive spots existed at road crossings. In point of fact the installation of magnesium at road crossings was substituted for a program of casing, because it could be done more cheaply and because it was thought it might be just as effective.

Immediate result of the first installations, which in the first year covered approximately 14 percent of the known corrosive spots and in the second year 20 percent, was a reduction in leak frequency to three in 1946. Some minor additions to magnesium installations in 1947 brought the leak frequency in that year to zero. These data are illustrated in Figure 2.

Probably it was true that by virtue of the previous leak experience and by repair work that had been done previously, the most progressive corrosive areas were eliminated, but the immediate reduction in leak frequency did not continue into successive years. Another circumstance entered at this time. A station construction program which entailed the use of maintenance crews for construction work and diverted them from normal corrosion prevention work was undertaken, so that during the years 1947 and 1948, few anodes were installed and no other corrective work was done. As was to be expected, because only one in five of known danger points was covered, the remaining corrosive areas continued to give trouble, and the leak frequency curve simply started again from a new base at approximately the same slope. Also, in the restationing of the line, operating pressures were increased from a maximum of 900 psi to a maximum of 1050 psi. Bearing in mind that this line had been progressively corroding and had innumerable pits of 80 percent to 90 percent penetration, the increase of operating pressures produced a number of leaks probably far above normal expectancy had the same operating pressures been maintained.

Before proceeding too far with the history of these operations, it may be well to consider some of the more intangible aspects of this sort of program. Early in the program the conclusion was reached that if the line currents and their point of departure from the pipe could be determined accurately, existing methods for locating corrosive areas would be improved. It was found to be true that changes and reversals of current flow took place along the pipe line in much shorter distances than previous concepts had indicated. In many measurements, major differences in current readings or actual reversals in current flow in 10-foot to 15-foot lengths of pipe were found, and wherever indications of current departure from the pipe were found, also destructive corrosion in progress was found. Usually such current changes occur where conventional 100 foot measurements of line current indicate no major change. It can be inferred from this that while long line current measurements may be useful in indicating the direction toward which to search for corrosive areas, of themselves they are not nearly so significant as short line measurements.

In agreement with field surveys and going one step farther with this reasoning, it is believed that the major portion of destructive corrosion comes about in very short cells along the line, each of which is in effect well isolated from adjacent corrosive areas.

In an effort to clear up this point laboratory tests were made under the premise that individual cells are isolated. Thus 12 individual cells were set up consisting of glass jars and solution in a manner to simulate an individual hot spot on the line.

The cell arrangement and the electrical circuits for this set-up may be observed in Figure 3. It will be noted that carbon electrodes are connected together with suitable resistances to form the earth circuit, and steel anodes are connected together with resistances to simulate a pipe line. The solutions in the order of their arrangement are as follows: 1. Ammonium hydroxide; 2. Sodium hydroxide; 3. Sodium hydroxide; 4. Tap water; 5. Tap water; 6. Sodium chloride; 7. Sodium chloride; 8. Tap water; 9. Tap water; 10. Sodium hydroxide; 11. Sodium hydroxide; 12. Ammonium hydroxide.

This arrangement then is similar to corrosive areas bounded on both sides by cathodic or non-corrosive areas and is considered to be roughly analogous to locally corrosive cells on a pipe line. It is to be noted that starting from each end of the line, currents flow in increasing magnitude toward the center, distributing back into corrosive cells progressively until the currents meet over cell No. 7.

Reference to Figure 4 shows the degree of corrosion on the steel anodes in these cells by number, and it is apparent that cells 1 and 12 are completely protected, cells 2, 3, 10 and 11 have only a minimum amount of corrosion, and corrosion progressively increases in the balance of the center cells. This experiment might be taken to correspond to several hundred feet of pipe in the ground with the center of the section in low or swampy ground comprising several more or less isolated active corrosive areas, and the ends of the section in high resistance, dry and non-corrosive surroundings.

Figure 5 shows the same experiment repeated but with magnesium anodes applied to cell No. 7. The currents have all increased in magnitude and all now flow to cell 7 with successive cells showing no decrease in current. From this it might be suspected that all cells are protected, and no corrosion should result. However, the figure shows color indications of corrosion in cells 3, 4, 5, 6, 8, 9, and 10. Reference to Figure 6, however, shows excellent protection in cells 1, 2, 3, 7, 10, 11, and 12 with very slight corrosion in cell 6 and slightly greater corrosion in cells 4, 5, 8, and 9.

In this experiment the corrosion situation is much improved in every cell over the previous experiment, and it may well be that the corrosion seen is only extremely localized corrosion in these very active low resistance cells, perhaps caused by local differences in composition of the steel itself. Another experiment was prepared with magnesium in all cells (Figure 7) and smaller currents than those observed when magnesium was concentrated in one cell were obtained, but in this case complete protection was achieved. An interesting point to note is that Plates

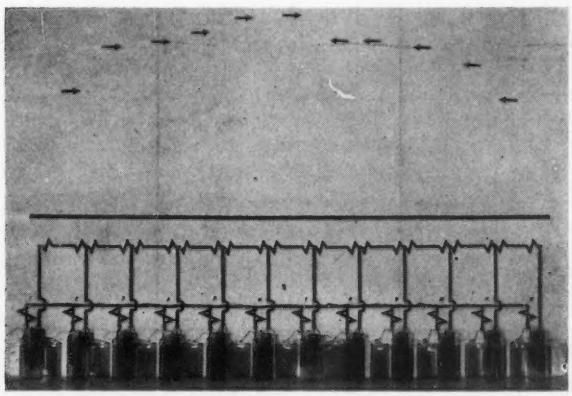

Figure 5—Magnesium anode protection in cell 7.

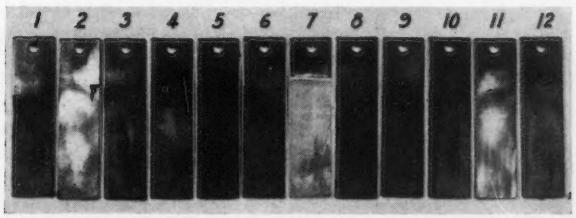

Figure 6—Plates after test shown in Figure 5.

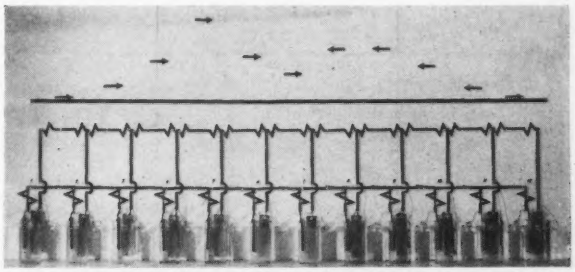

Figure 7—Magnesium anode protection in all cells.

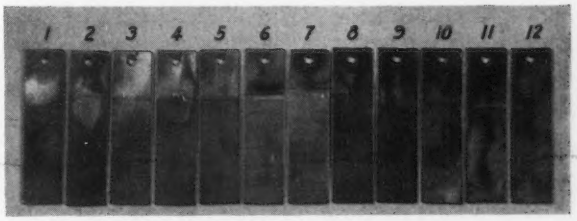

Figure 8—Plates after test shown in Figure 7.

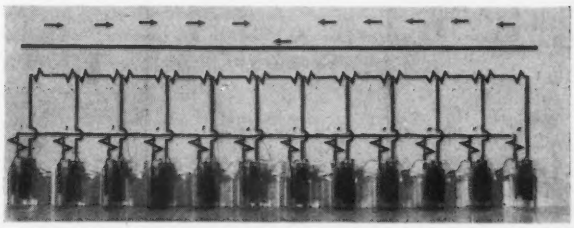

Figure 9—One-quarter inch magnesium anode protection in cells 3-5-6-7-8-9.

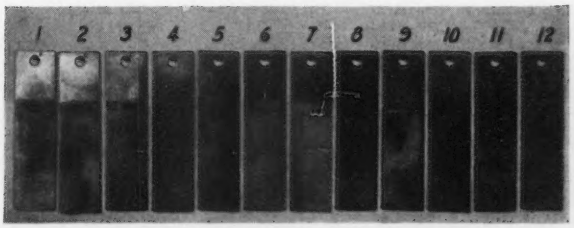

Figure 10—Plates after test shown in Figure 9.

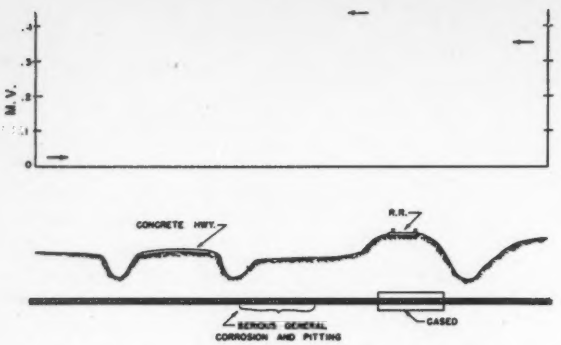

Figure 11—Line current survey at Mile Post 120.3 in 1944.

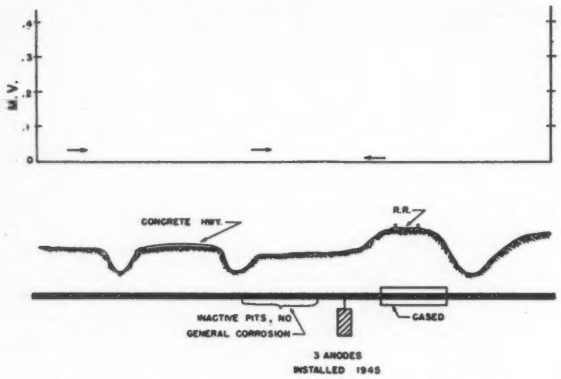

Figure 12—Line current survey at Mile Post 120.3 in 1949.

6, and 7, which nominally should be most corrosive, have a coating or film of magnesium salts, demonstrating complete polarization. This is shown in Figure 8.

Similar situations are noted on the lines, where the easiest points to protect are the lowest resistance areas where normally corrosion would be most severe, although on the lines actual platings of magnesium were not found.

In the light of the last experiment another was prepared, again using exactly similar cells and plates but reducing the quantity of magnesium to an anode immersed only ¼-inch in the solution. Figure 9 shows only minor indications of corrosion in the color of the cell liquid, and Figure 10 confirms only minor corrosion in cells 4, 5, 8, and 9, which again may be due to the extremely active atmosphere of a liquid cell such as is used here. However, this also shows excellent protection in the low resistance cells and lesser protection in the high resistance cells.

It is quite obvious that it is not possible to duplicate exactly the performance of corrosion as it exists in the field in these laboratory experiments, where full cells using carbon cathodes simulate the ground. Corrosion in these cells, when existent, is much more violent due to the intensity of contact in an aqueous solution and also due to the relatively low resistance. Further laboratory experiments are planned where the conditions of various experiments will be altered widely enough to evaluate all the indicators they might produce.

Briefly stated, conclusions from the laboratory experiments are that line currents do flow toward the hot spots, and in general the application of magnesium as a protective anode increases the current flow to the individual cell, although this is far from an invariable rule. The best interpretation seems to be that inflowing current to a corrosive area is increased by anodes if the area is of low resistance, but may be decreased by anodes in a relatively high resistance area which is corrosive. While the laboratory experiments indicate different effectiveness in these cases, field data seems to show that protection is achieved in either case.

These laboratory experiments seem to point up another important fact which is also confirmed by field work with magnesium. The protection achieved by magnesium anodes is strictly local. If one thinks of this action of magnesium as similar to a small rectifier installation, the currents by comparison to any commercial rectifier installation are microscopic. If on the other hand one can think of magnesium anodes only as a surface of metal which corrodes preferentially with respect to steel, then the surface of magnesium exposed to earth and corrosion is, relative to pipe surface, again very small, and beneficial effects should not be expected to reach out to long distances.

It is a fact that in field measurements some interaction is found between individual hot spots which have magnesium anodes, but basically it is believed that each hot spot should be treated as a separate entity and be protected with its own anodic installation. The main issue which should not in any of these considerations be overlooked is that where magnesium is applied in sufficient number or weight it does protect against corrosion.

Some observations on field installations are presented. Figure 11 depicts a railroad crossing and concrete highway at mile post 120.3 and shows the direction and relative magnitude of currents in millivolt drops on 5-foot length measurements as taken in October 1944. Between the concrete highway and the railroad there was serious general corrosion and severe pitting. In 1945 three anodes were installed just south of the cased railroad crossing and between the railroad crossing and the concrete highway. These three anodes developed a current to ground of 150 milliamperes, and the line currents decreased as illustrated in Figure 12.

Subsequent inspection of this area revealed pits completely inactive and no general corrosion. In this particular instance, if the line current measurements are accurate, these currents had materially decreased but local corrosion protection had been completely achieved.

Figure 13 records a cased railroad crossing on a fill and an apparent corrosive area in the railroad borrow pit. Inspection of this area in 1944 indicated heavy corrosion and pitting with currents as indicated. Four anodes were installed later in 1944, and subsequent current measurements showed current reversals with current flowing away from this area on one side where previously it flowed into the area. Again, later inspection (Figure 14) indicated no gen-

eral corrosion and no apparent activity in corrosion pits. Again demonstrably, this area is protected.

An interesting thing to note in connection with this installation is that four anodes provided only 60 milliamperes of current, which is a fraction of the current usually obtained from this type of installation. The usual current approximates 100 mils per anode, whereas in this instance each anode provides only 15 mils. This apparently conforms to one of the laboratory experiments which indicated that high resistance areas are protected without increasing the current in-flow to the area.

If this were an isolated example, it might not be significant, but complete protection has been achieved on lines in Massachusetts where the soil resistivities are in excess of 15,000 ohms and where measurable anode currents could be obtained only by the use of magnesium ribbon, which provides an extreme amount of surface per pound of magnesium.

Figure 15 shows another area at Mile Post 217.2 where a number of current reversals take place in a very short distance on the pipe line, with currents relatively high. By inspection, only the points to which the currents flow are corrosive and there was only one deep pit, which would have caused a leak soon.

In 1949, two anodes were installed on each side of the road to protect the two borrow pits and the compacted soil under the gravel road. Inspection in February of 1950 indicated good pipe all the way through this area with no corrosion apparent. In this case the currents in the line were quite high before installation of anodes, but after installation quite low, and in this case, because of the relatively low soil resistance, each anode produced a current flow of approximately 80 mils. Again complete protection is achieved.

Figure 16 shows a survey on one mile of pipe from Mile Post 225 to 226. The area includes a railroad crossing, a bad wet spot, a drain tile installation, a lane over which light traffic flows, and a concrete highway. This survey was made before the installation of anodes in September 1949, and it will be seen that several current reversals existed over this one-mile section, although all currents are relatively low. There were active pits north of the railroad and near the drain tile installation.

In September 1949, eight anodes were installed between the two insulating flanges to protect the known corrosion there, and two anodes were installed north of the railroad to protect the area where active pits had been found previously. Subsequent inspection (Figure 17), in February, 1950, disclosed no active pits nor apparent new corrosion. In this instance it will be noticed that the currents were increased and also indicate departure from the line at or near the country lane where consequently corrosion might be anticipated. From the current survey only, anodes are expected to be installed at this point, and subsequent work will be done to verify this conclusion.

These few instances are detailed, out of many which are in the records, to show that protection can be achieved and that invariably corrosion is located by the direction of local current flow. In them-

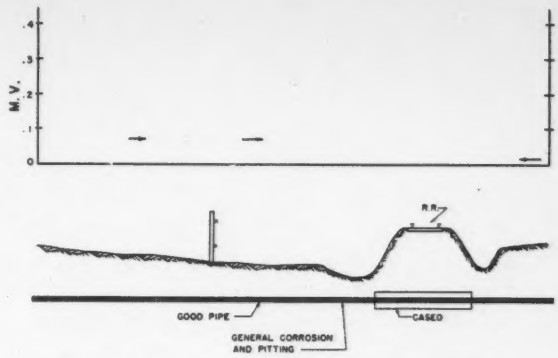

Figure 13—Line current survey at Mile Post 216.6 in 1944.

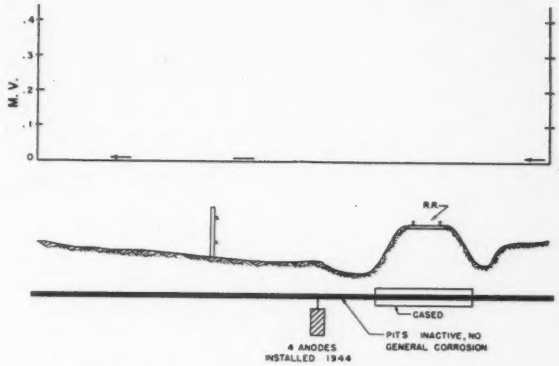

Figure 14—Line current survey at Mile Post 216.6 in 1946.

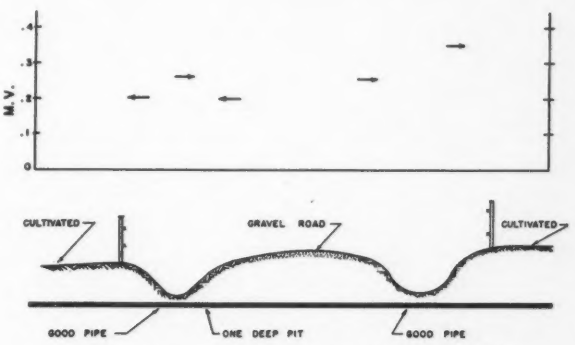

Figure 15—Line current survey at Mile Post 217.2 in 1943.

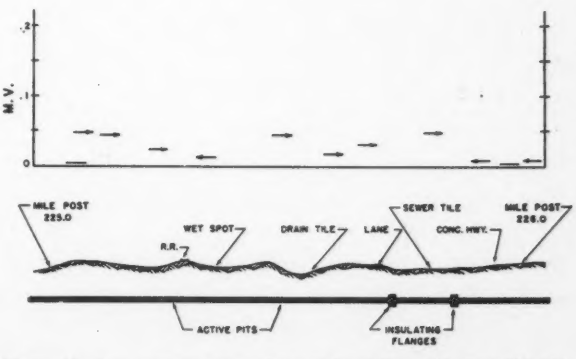

Figure 16—Line current survey of one mile of line, Mile Post 225-226, before magnesium anode installations.

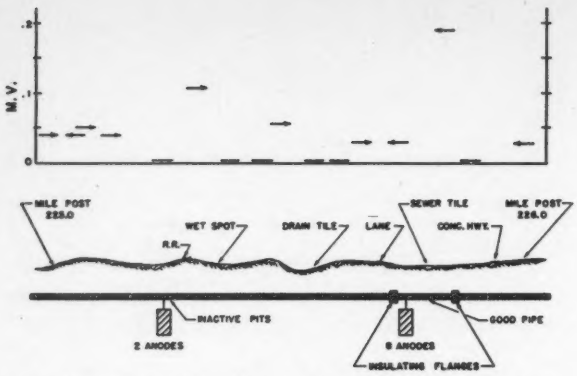

Figure 17—Resurvey of line shown in Figure 16, after partial protection by magnesium anodes.

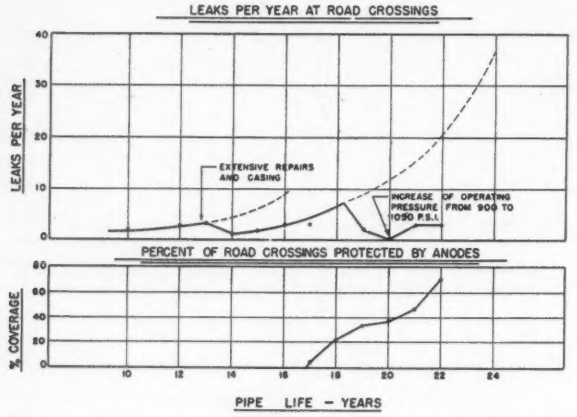

Figure 18—Leak frequency and percent of locations protected for road crossings.

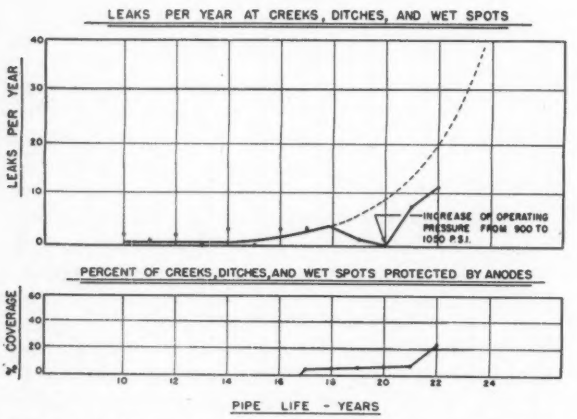

Figure 19—Leak frequency and percent of locations protected for ditches and wet spots.

selves these isolated instances tend to prove the localization of cell action on the line, and they certainly prove the effectiveness of installed anodes if the anodes are placed at or immediately adjacent to corrosive areas.

In the final analysis there are several ways to protect against corrosion. They are as follows: coating of lines; coating of lines and additional cathodical protection; protection of uncoated lines by the application of magnesium anodes or rectifiers, or use of various combinations of these methods. In the construction of new lines at this time, recommendation is not made that they can most economically be laid uncoated and protected by magnesium. In the case of a line already laid without coating, in which the choice must be made between repairing as leaks appear, endeavoring to protect with high current densities generated by windmills or rectifiers, protecting by local applications of magnesium, or finally taking up the line for reconditioning and coating, it is believed that from the experience obtained on the 8-inch North Line the method used thereon can be shown to be the most economic approach.

Figure 2 mentioned previously, which projected leak frequencies and actual leaks through pipe line life from 10 years to 23½ years, only shows a portion of the picture. Actually because of the method of approach this line should be considered as comprising two groups of corrosive areas because protection of the types of areas was undertaken at different times. These groupings consist of those portions of the line whose hot spots are the road crossings, and secondly, those portions of the line whose hot spots are creek crossings, or other low, wet or low resistance areas.

Figure 18 shows leak frequency curve on the section involving road crossings. It also shows the proportions of those road crossings which have been protected by anodes. Thus it will be seen that with 70 percent of protected road crossings and 30 percent unprotected the leak frequency is 15 percent of that properly to be expected without protection. In other words, whether a sufficient number of anodes were placed at individual points, the data still indicates that leak frequency has been reduced in greater proportion than the proportion of protected areas. In point of fact the leak frequency at 22 years and at 13 years of pipe line life is the same. At 13 years no major repairs or magnesium installations had been made. At 22 years some considerable earlier repairs had been made and 70 percent of road crossings had anodes. But in the meantime operating pressures had been raised from 900 to 1050 psi and the line was nine years older.

The case for anodes on road crossings on the basis of these data would seem entirely conclusive. Leaks per year at creeks, ditches, and wet spots (Figure 19) shows somewhat the same pattern although they have a much lower degree of protection. At the end of the twenty-second year of pipe line life 22 percent of these known hot spots were protected. Against projected leak frequency of 20 for these areas there were 12 leaks, a 40 percent decrease against 22 percent coverage. Until complete protection is achieved none of these data can be considered absolutely conclusive; certainly, however, conditions are improved, and most significant is the dollars and cents or economic factor.

Illustrating overall success, other charts based on the following premise have been prepared. Over the majority of the pipe line life the average cost of local spot repairs, brought about either by leaks or the an-

ticipation of leaks in a given area is approximately $1400 per job. On the first of these charts (Figure 20), the number of repair jobs per year, inclusive of both classifications and also the percent of locations protected are plotted.

The next figure, 21, shows this same projection translated into dollars and cents. The shaded area is the cost of magnesium protection so far installed, and the unshaded area above this the saving achieved compared to the projection of leak and repair costs without protection. These figures should be convincing.

In the preparation of the paper it became apparent the data already collected had not been properly evaluated. These data demonstrated reasonably conclusively that the program was started too tentatively where actually it should have been accelerated to cover all known hot spots. It is particularly true in the case of this line because it is an important part of the transportation system, and repair jobs entail loss of pumping time. The best safeguard observed against such losses is the immediate protection of all known hot spots and continued search for those spots not yet known.

The average cost per anode is approximately $15 installed. The average life per anode is apparently six years. The cost of reconditioning and coating this 320 miles of pipe would be in excess of $1,500,000. The interest on this money at 4 percent per annum is $60,000. The annual cost of 4000 anodes, which is estimated will cover the line, is $10,000 on a 6-year life basis. A net saving against the interest charge on the reconditioning cost is $50,000 per annum. The economics of this approach seem to be unimpeachable, and there is the additional advantage that service through the line continues relatively uninterrupted.

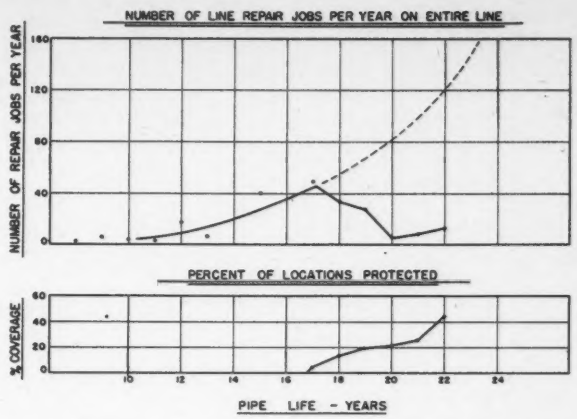
NUMBER OF LINE REPAIR JOBS PER YEAR ON ENTIRE LINE
NUMBER OF REPAIR JOBS PER YEAR
PERCENT OF LOCATIONS PROTECTED
% COVERAGE
PIPE LIFE - YEARS

Figure 20—Number of repair jobs and percent of locations protected.

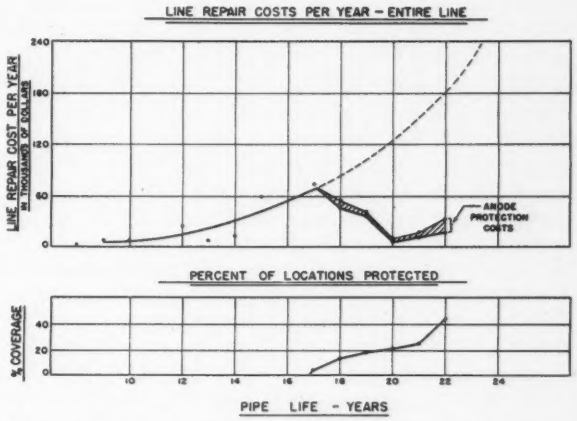
LINE REPAIR COSTS PER YEAR - ENTIRE LINE
LINE REPAIR COST PER YEAR IN THOUSANDS OF DOLLARS
ANODE PROTECTION COSTS
PERCENT OF LOCATIONS PROTECTED
% COVERAGE
PIPE LIFE - YEARS

Figure 21—Costs of repair jobs and magnesium protection, with percent of locations protected.

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DISCUSSION

Question by I. B. Tietze, Phillips Petroleum Co., Bartlesville, Okla.:

I should like to have Mr. Smith present the economics of his idea. This would include the added investment cost of the coating plus cathodic protection losses in products, cost of down-time. Consideration should also be given to the use of lighter wall pipe when coating is used—as an example, 3/16-inch wall 8-inch pipe when coated can be operated at 1000 lbs. or more. Would Mr. Smith recommend laying this pipe bare? If this weight pipe is laid bare, what correction do you make in increased anticipated maintenance expense to reconcile anticipated expense on this line with actual expense on operating lines of heavier wall?

Authors' Reply:

I cannot give all of the economics of this in a brief answer, and in fact at this stage of development we are not entirely certain of the economics. However, the cost of a coating on a new line is sufficient that normal interest charges on this capital investment will approximately pay for the cost of anodes, and in view of the fact that pipe line pressures are constantly increasing we prefer to put weight of metal in the pipe rather than go to the thinner-walled pipe. Some of these factors may change as the use of high tensile steel becomes more general in pipe lines.

Question by J. M. Pearson, Sun Physical Laboratory, Newton Square, Pa.:

What method is used to check continued operation of anodes?

Authors' Reply:

All of our anodes are connected to the pipe with separable leads or junction boxes. By the use of these junction boxes we check the current per individual anode, originally on a quarterly basis and more latterly on a semi-annual basis. In our experience the anodic current stays approximately level through the life of the anode and cuts off rather sharply during the last three to six months of anode life. As we accumulate experience and have better life factors this will become less and less of a problem.

Corrosion Fatigue*

The Influence of Disarrayed Metal

By D. WHITWHAM and U. R. EVANS***

Synopsis

It is not certain from theory whether a preliminary period of dry fatigue should lengthen the normal corrosion-fatigue life by strain hardening, or shorten it by producing disarrayed metal which may be particularly susceptible to corrosion. An answer to this question was obtained by carrying out two-stage tests; a period of dry fatigue was followed by corrosion fatigue up to failure; for comparison, a second set was submitted to corrosion fatigue without previous dry fatigue. With both cold-drawn and annealed wires, little or no change in corrosion-fatigue life was brought about by preliminary dry fatigue under the conditions tested.

A metallographic study was also made of changes during air-fatigue and corrosion-fatigue processes. For this purpose, the annealed wires were reduced by electropolishing to remove surface defects and to avoid deformation. In air fatigue, the repeated application of a stress, greater than the fatigue limit, results in the plastic deformation of many grains as a preliminary to the development of micro-cracks and failure. Simultaneously, heat is generated in the specimen and a superficial oxidation of the surface follows.

In corrosion fatigue, at a stress below the air-fatigue limit, a localized attack leads to stress intensification and hence to corrosion along slip bands. Attack spreads around the circumference of the wire, with subsequent weakening.

The major damage, estimated by loss in tensile strength, occurs towards the end of the process, both in air fatigue and corrosion fatigue. Cracking is mainly transcrystalline, but may occasionally be intercrystalline for distances of a few grain diameters.

CORROSION-FATIGUE cracking is often ascribed to a preferential attack of disarrayed material along slip bands produced during the application of alternating stress. If this suggestion is correct, there is danger that material which has already been subjected to dry fatigue, would be abnormally susceptible to corrosion fatigue if precautions against corrosion were temporarily relaxed. Against this, it is by no means certain that disorganized material which is subsequently exposed to corrosive influence is so susceptible as material which is exposed to corrosion during the process of derangement.

It appeared important to ascertain whether the increased susceptibility really does arise, or whether the strain-hardening effect of prior fatigue leads to an improvement in the corrosion-fatigue life.

Experimental Work

The material used in the experiments was in the form of wire specimens 15 in. long and 0·1 in. dia., available from a previous research[1]; these were produced† from a single billet of mild steel by cold drawing in two passes a patented steel rod of 0·144 in. dia. The percentage analysis of the material was C 0·19, Si 0·07, S 0·03, Mn 0·78, P 0·02. Metallographic examination showed the wire to be reasonably free from non-metallic inclusions. It had an ultimate tensile strength value of 48 tons/sq. in., a Young's modulus value of $13{\cdot}4 \times 10^3$ tons/sq. in., and a fatigue limit (wires coated with zinc-chromate/vaseline mixture) of 21 tons/sq. in.

Techniques Used in Research

Vacuum Annealing

For certain purposes annealed specimens were required. A sufficient stock of such wires was obtained by heat-treating a single batch in a small tube furnace, which was continuously evacuated by a Hyvac pump. The furnace used had been wound to give a uniform temperature over the middle 4 in. of its length (18 in.); outside this region the temperature decreased steadily towards the ends of the furnace. Thus, although each part of a given wire did not receive the same heat-treatment, every wire was subjected to the same furnace conditions. The furnace was continuously evacuated and the temperature, measured at the centre of the tube, was taken up to 950° C. over a period of 3 hr., and maintained for ½ hr.; then the current was cut and the specimens were allowed to cool in the furnace.

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* Dr. Whitwham was in the Department of Metallurgy at the University of Cambridge, and is now working with Professor Chaudron and Dr. Lacombe at Vitry.

** Dr. Evans is in the Department of Metallurgy at the University of Cambridge.

† By Messrs. Bruntons, Ltd., Musselburgh, Scotland.

After this treatment, the wires had been oxidized superficially to give first-order straw and blue interference tints; this showed that a trace of oxygen had been present, but the amount needed for interference-colour films is very small.

Electropolishing

In the second part of the research, the smooth surface demanded in fatigue testing was obtained by electropolishing. The nature of the anodic process changes during a polishing cycle, as shown by measurements of the anode potential. As the metal develops a very bright surface the potential may even approach that of the oxygen electrode. This does not mean that the specimen stops dissolving, and in practice the surface layers are removed smoothly and continuously.

By the method described below, the rate and total amount of metal removed in polishing was controlled until all major defects of surface had disappeared. The method is very satisfactory in avoiding the cold working or deformation of the specimen characteristic of mechanical polishing; the resulting surface is perfect for metallographic examination, since any remaining defects can be detected much more certainly than on the finely ground surface commonly used in fatigue research.

The method of polishing, based on Jacquet's[2] most recent procedure, was modified slightly to deal with the present specimens; the bath, which is claimed as non-explosive, was composed of glacial acetic acid 1000 c.c., 60% perchloric acid 50 c.c. The specimen wire was mounted at the centre of a vertical glass cylinder of 3-in. dia., which was filled with enough electrolyte to leave 2 in. of the wire above the liquid level; an electrical connection was made on this dry portion. A cylindrical cathode of aluminium gauze was fitted tightly around the inside of the cylinder. Electropolishing was carried out at an applied voltage of 110, with an external resistance of 30 ohms in series with the polishing cell. Under these conditions a current/time curve of the form shown in Figure 1 was obtained; the oscillations of current are at first rapid, but their frequency and amplitude fall off with time until, finally, a constant current is attained, at which stage polishing is known to be complete.

After a standard time, the current was switched off, the wire was inverted, and polishing was continued—a plan adopted to minimize any slight differences in 'throwing power' of the bath. Thus, the diameter of the wire was reduced uniformly, except for the end portions which spent half the time outside the polishing bath.

When the bath had been used for a considerable time, or when its temperature had been increased owing to the heating effect of the current, it was found to produce etching. This was satisfactorily avoided by carrying out a two-stage treatment of the wire, the first stage consisting of a 'rough' polishing, and the second of a short (2 min.) polishing in a fresh or nearly fresh bath. The wire specimen was then washed thoroughly under running water and carefully dried with filter paper. The final result was a highly polished specimen, in which only the pearlite areas had been lightly etched.

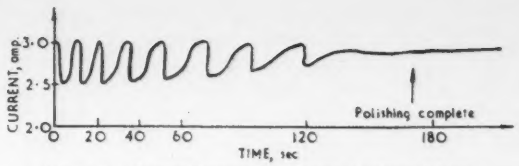


Figure 1—Current fluctuations during electropolishing.

Surface Grinding

In the first part of the work, wires were used in the cold-drawn state; these were prepared for fatigue testing by grinding to 000 emery over a length of approximately 3 in. at mid-span. A preliminary coarse grinding with No. 1 emery for 5 min. was essential to remove major defects from the wire surface. These comprised a single linear groove along the whole length of each wire, and a finer helical trace around the circumference; they were present in all the wires, as received, and presumably originated in manufacture. The final scratches (000 emery) were circumferential.

Fatigue Testing

All fatigue and corrosion-fatigue tests were carried out in a Haigh-Robertson machine, designed for wire test-pieces. After preparation, the specimen was fixed in position and a small stress was applied. The speed of the driving motor, which was controlled by a Variac auto-transformer, could be quickly adjusted to the running speed of approximately 6000 r.p.m. by following the changes observed on a stroboscope disc. The tailstock was then adjusted until the specimen had been bent to the required angle and the test was timed from this point. Minor adjustments of the motor speed and of the angle of flexure were necessary in the first stages of each test, but after the machine and test-piece had settled down, the speed of the motor remained at approximately 6000 r.p.m.

To eliminate any tendency of the specimen to pick up or develop lateral vibration, it was found essential to fix a smooth glass rod, mounted loosely, in such a position as to touch the rotating wire gently towards one end.

Corrosion

The feeding arrangement used in corrosion-fatigue tests was similar in principle to that used by Simnad.[1] Because of the large volume of liquid needed, the salt solutions were usually made up from tap water, and these were in continuous contact with the laboratory atmosphere, though protected from dust. The corrosive solution was fed on to a small area of the specimen, at mid-span, at the rate of approximately 1·5 cc./min. The specimen was covered with a layer of polystyrene lacquer to limit to 0·5 cm. the length of wire corroded.

Cathodic Cleaning

To examine the surface of the wire after corrosion fatigue, the corrosion product, consisting largely of brown moist rust, was in some cases removed by

cathodic treatment in sodium carbonate; such treatment had to be carried out soon after the test, otherwise large patches of rust remained adherent.

The portion to be cleaned was made the cathode in 5% sodium carbonate solution, using a steel anode. The applied voltage was 6 and the treatment was normally restricted to 5 sec.

Two-Stage Tests

Determination of Air-Fatigue Limit

To discover whether the fatigue properties of the available wire had changed during storage, the air-fatigue limit was re-determined. Before the test, each specimen was ground to 000 emery, as described on page 29. The results were as follows:

Stress, Range, ± tons/sq. in.	Life, Kilocycles
29·6	48
25·7	257
24·5	421, 475, 335
23·9	1061
23·0	859, 1252, 840, 1131
22·5	851
22·0	2050, 1804, 1455, 1832
21·8	16,614,* 9040*
21·7	14,912,* 3096
17·2	10,096*
13·0	9503*

* Signifies unbroken

From these results, the air-fatigue limit would appear to have a value of 21·5 tons/sq. in. approximately, which agrees well with 21·0 tons/sq. in. as found by Gould.[3]

With each specimen set up, the zero error on the swinging headstock was of the order of 0·2-0·5°. The corrected angle used in calculating the stress is estimated to be accurate to ±0·1° and the nominal stress values should then be accurate to ±0·26 tons/sq. in. Such an error would account for some deviation, but it does not explain the whole scatter observed; this must be attributed to accidental variations between different wires.

Study of Air Fatigue Followed by Corrosion Fatigue

It is equally possible, on theoretical grounds, that a preliminary period of 'dry' fatigue could shorten or lengthen the life of a specimen under corrosion-fatigue conditions. To determine what takes place in practice, two-stage tests were carried out, in which the first stage consisted of dry fatigue and the second of corrosion fatigue to failure; for comparison, one-stage tests were also carried out, consisting of corrosion fatigue to failure. The experiments on cold-drawn wire were divided into two groups of tests, carried out at a stress range (i) above, and (ii) below the fatigue limit. The numerical results are set out in Tables I and II.

TABLE I

Results of Tests on Cold-Drawn Wire Carried Out Below the Stress Range

Air Fatigue, Kilocycles	Corrosion Fatigue, Kilocycles	Air Fatigue Followed by Corrosion Fatigue, Kilocycles	
		1st Stage	2nd Stage
Unbroken 10,000*	733	10,028*	952
	852	25,090*	997
	592	25,586*	1059
	816	26,118*	772

* Specimen unbroken.

TABLE II

Results of Tests on Cold-Drawn Wire Carried Out Above the Stress Range

Air Fatigue, Kilocycles	Corrosion Fatigue, Kilocycles	Air Fatigue Followed by Corrosion Fatigue, Kilocycles	
		1st Stage	2nd Stage
2050	297	1000*	445
1804	375	1015*	401
1455	475	1560*	338
1832	403	1000*	391

* Specimen unbroken.

(i) *Below Fatigue Limit*—The stress was 17·2 tons/sq. in., the material was cold-drawn mild-steel wire, ground to 000 emery, and the corrodent was an aerated M/10 KCl solution.

(ii) *Above Fatigue Limit*—The stress was 22·0 tons/sq. in., the material was cold-drawn mild-steel wire, ground to 000 emery, and the corrodent was an aerated M/10 KCl solution.

When the specimen is stressed to a value below the fatigue limit, it appears that a preliminary stage of 1-2½ million reversals of dry fatigue may cause a slight improvement in the subsequent behaviour of the material under corrosion-fatigue conditions. The improvement is small, however, and may fall within the experimental scatter of the tests. It is reasonable to suppose that shorter periods of dry fatigue would have even less effect on the corrosion-fatigue life.

Considerably longer periods of dry fatigue could have established more certainly whether the slightly improved behaviour was, in fact, real. This point was not investigated, since the time required for each individual test would be 1-2 weeks.

When the applied stress is above the fatigue limit, the life of the specimen, even in dry fatigue, is limited. The stress value for investigation was therefore chosen to give a fairly long life under these conditions. Originally, the intention was to measure the effect of different amounts of dry fatigue on the subsequent life in corrosion fatigue. In fact, only two such points were obtained and, as the corrosion-fatigue life was not significantly altered by previous dry fatigue, the experiments were discontinued.

It is quite probable that short periods of dry fatigue, above the fatigue limit, would slightly improve the subsequent corrosion-fatigue life and that longer periods, when a certain amount of fatigue damage had been produced, would shorten it somewhat. However, using the present testing method, such changes could be established only with difficulty owing to the relatively large scatter of results. The matter possesses limited practical importance since it is unlikely that structures would be deliberately subjected to stresses greater than their fatigue limit.

A further group of tests, below the fatigue limit, was carried out on annealed wire specimens because it was considered that any effect of previous dry fatigue on the subsequent corrosion-fatigue life might be more marked with an unworked material, in which there would be no disorganized material at the outset of the test.

Wire specimens were, therefore, annealed at 950°

C. and their surface defects were removed by electropolishing, as described on page 29, to avoid deformation of the surface. A solution of M/100 KCl instead of M/10 KCl was used to increase the corrosion-fatigue life, and thus to determine more easily any significant change in its value. Annealing of the wire causes a change in all its mechanical properties, including the value of Young's modulus which is required for calculating the applied stress from the angle of flexure; the value of Young's modulus was assumed to be $13{\cdot}4 \times 10^3$ tons/sq. in. This may not be quite correct, but any error will be the same in each test. The applied stress range was below the air-fatigue limit for the material, based on ten million reversals of stress.

The stress was 11·8 tons/sq. in., the material was annealed mild-steel wire with electropolished surface, and the corrodent was an aerated M/100 KCl solution. The results are given in Table III.

Thus, with annealed mild-steel wire, tested under the present conditions, it was once again found that a preliminary period of air fatigue had little or no effect on the subsequent behaviour of the material under corrosion-fatigue conditions.

Metallographic Studies

Gough and Sopwith,[4] during a microscopic examination of the corrosion-fatigue process in aluminium, observed that corrosion had occurred with the formation of many small pits, a localized attack with larger pits, and preferential attack on slip bands.

In the present work, parallel studies have been made on polished steel wires at different stages of both the air-fatigue and corrosion-fatigue processes. Annealed wire specimens were used throughout; these were electropolished to remove surface defects, the resulting surface being eminently suitable for immediate micro-examination.

TABLE III

Results of Tests on Annealed Wire Carried Out Below the Stress Range

Air Fatigue, Kilocycles	Corrosion Fatigue, Kilocycles	Air Fatigue Followed by Corrosion Fatigue, Kilocycles	
		1st Stage	2nd Stage
Unbroken 10,000*	2387	9638*	1831
	1166	10,285*	1636
	1383	9503*	2278
	1919	10,702*	1549

* Specimen unbroken.

TABLE IV

Changes in Tensile Properties of Mild-Steel Annealed Wire Brought About by Fatigue

Specimen No.	Reversals of Air Fatigue	AFTER AIR FATIGUE	
		U.T.S. Tons/Sq. In.	Elongation, Minute
1	0*	32·15	6·2
2	51*	32·60	5·4
3	100*	32·60	4·9
4	289*	32·95	3·3
5	495*	33·90	3·15
6	546*	33·14	3·1
7	457	....	....
8	506	....	....
9	632	....	....

* Specimens unbroken.

Air Fatigue Followed by Tension

Some electropolished annealed wires were subjected to different (known) numbers of reversals of stress, above the fatigue limit, and were then removed for micro-examination. To open up any surface micro-cracks produced in this process, the ends of each wire were cut off to make a tensile specimen 10 in. long. The specimen was then broken in a tensometer and its tensile properties were recorded. The object of these tests was:

(i) To discover the stage of fatigue at which micro-cracks are formed, and their place of origin

(ii) To find what changes of tensile properties are brought about by fatigue.

The latter information is summarized in Table IV, and the results of micro-examination are described on page 32.

The stress was 16·55 tons/sq. in., and the material was annealed mild-steel wire, with electropolished surface.

Changes During Air Fatigue

During an air-fatigue test on polished annealed wire, the repeated application of stress, greater than the fatigue limit, results in the plastic deformation of many grains as a preliminary to the development of micro-cracks and failure. Simultaneously, heat is generated in the specimen and a superficial oxidation of the surface follows. Air fatigue should probably be regarded as a case of corrosion fatigue; whether the corrosion reaction is something more complicated than direct oxidation is uncertain.

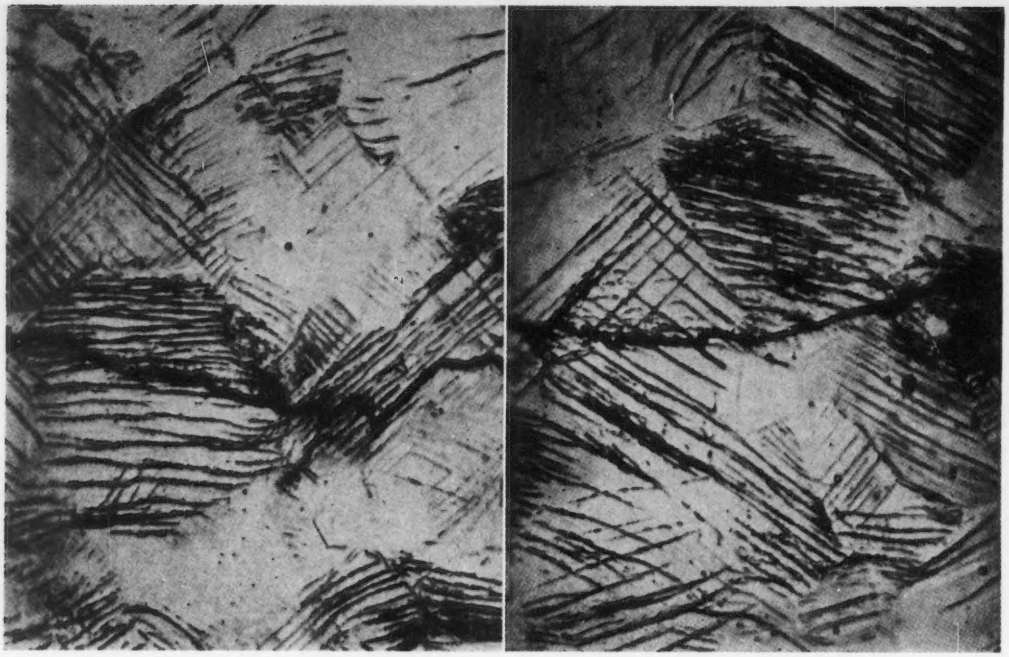
When stress is applied to the wire by bending it into an arc, the peak stress occurs at mid-span and falls off in value on either side of this point. Changes therefore tend to occur first, or are more pronounced, at mid-span, but they are not restricted to this region.

Heat Generation—From the start of the test heat is generated in the wire which quickly becomes too hot to touch at the centre, though the temperature falls off towards the ends. The maximum temperature attained at any point will be governed by the relative rates of heat lost to the surroundings and heat produced by internal friction. At the centre of the wire the measurable temperature is probably of the order of 200° C., but at certain localized regions, such as slip planes, it may temporarily be much higher.

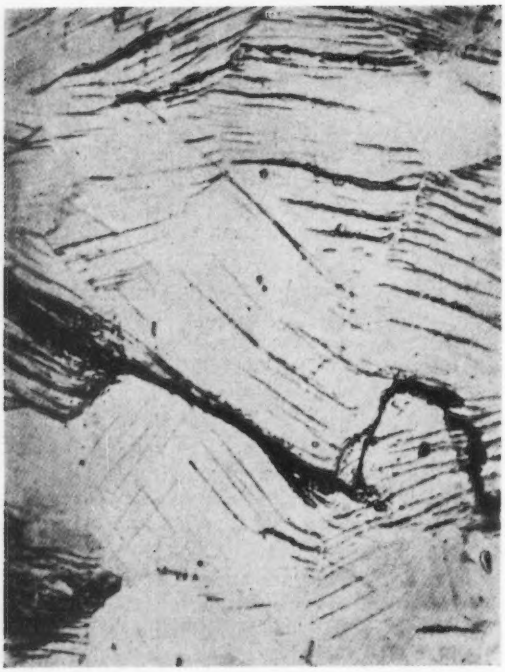
Oxidation—The increased temperature of the wire which develops during the fatigue process causes superficial oxidation of the polished surface and produces interference tints of first-order straw and blue. The tints suggest that the average thickness of this film is greatest at the centre and remains thin (invisible) at the ends of the wire. On a micro-scale the tints are not uniform but vary slightly from grain to grain because of differences in orientation.

Deformation Marks—Marks, presumably caused by plastic deformation, appear on the polished surface of the wire at an early stage of the fatigue test; these marks vary in character from the delicate trace of the usual slip band to a coarse black zone or band.

By fatigue-testing a wire at 16·55 tons/sq. in., and



A B



C

Figure 2—Formation of micro-cracks in relation to deformation marks: A and B serrated cracks. Air-fatigue above fatigue limit. X 1000.

then interrupting the test at various stages for micro-examination, it was shown that deformation marks were produced after only 10 kilocycles of rotation. As the test was continued, the deformation marks began to develop over a greater length of the wire (up to 8 in.); at mid-span, however, these marks were more numerous. After 200 kilocycles all the deformation marks were removed by electropolishing for 2 min.; the test was then continued and again the marks reappeared and increased in number until failure occurred.

In certain grains two systems of deformation marks were noted, indicating that slip had occurred on two sets of planes (*see* Figures 2*a*, *b*, and *c*. It may be noted also that the coarser markings are much thicker than the usual slip band and, in general are more widely spaced and less straight. Most, if not all, of these deformation marks must have been produced when the wire was well above room temperature; they should therefore reflect any modification of the slip process caused by the increased temperature. Each coarse line possibly represents a zone in which several slip planes, and not one only, have been used in a 'forward-backward' slip deformation.

The deformation marks arise probably from slight changes in the topography of the grains, because they may be removed entirely on electropolishing for 3 min., as shown by Figures 3 and 4. On etching the repolished specimen in 2% nital, fainter traces of plastic deformation are again revealed, as may be observed by comparison of individual grains in Figures 3 and 5. The marks developed by etching are, however, on a much finer scale, and do not correspond in detail to the original marks.

Finally, if a polished specimen, showing the coarse deformation marks developed by fatigue, is etched in 2% nital without an intermediate electropolish, these marks disappear, but are replaced by a finer-scale structure which is visible on most of the grains (cf. Figures 6a and b). No explanation of this effect can be given, but the phenomenon, together with the others described, may have useful applications in revealing the distribution of strain on a micro-scale.

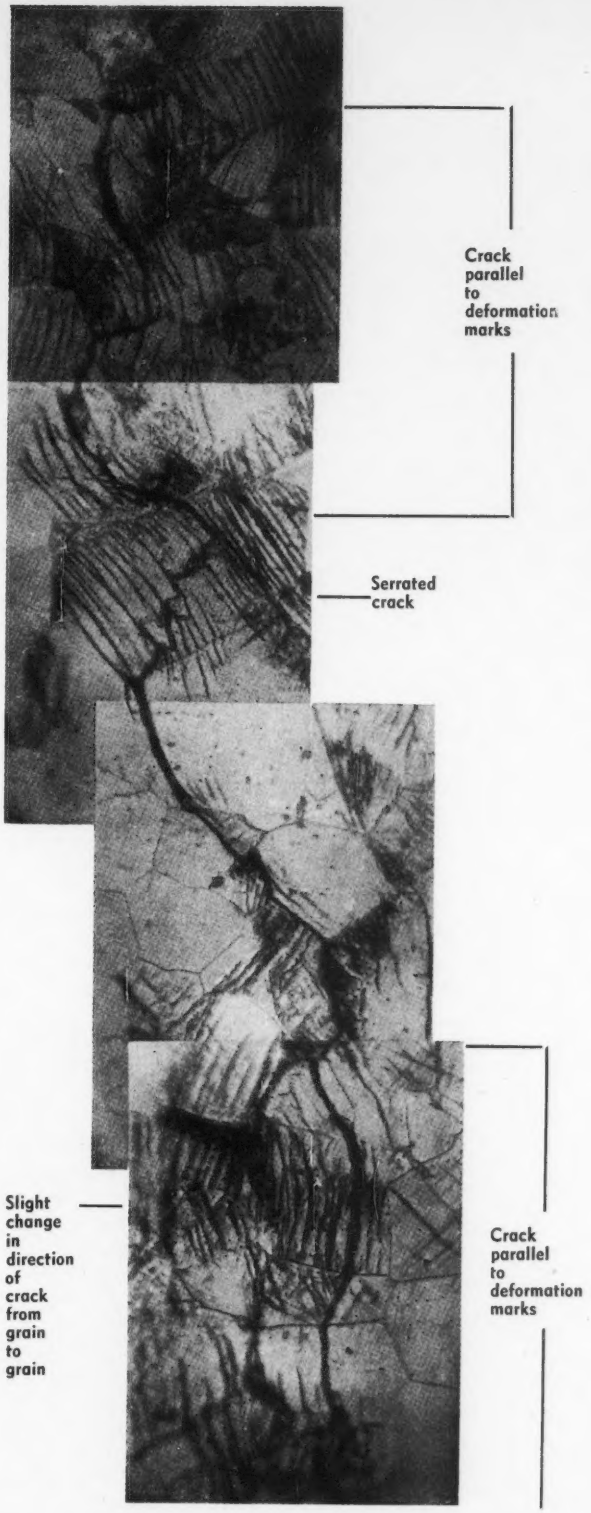

Crack parallel to deformation marks
Serrated crack
Slight change in direction of crack from grain to grain
Crack parallel to deformation marks

Figure 3—Composite photograph of peripheral crack and deformation marks obtained by rotation of wire for each of four separate exposures. Electropolished, air-fatigue to failure. X 500.

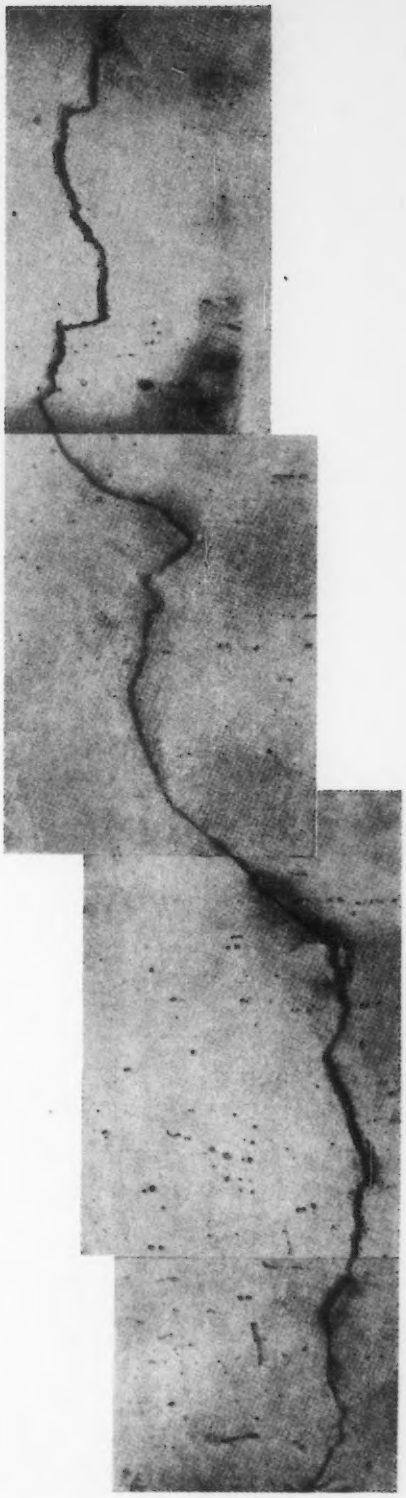


Figure 4—Specimen of Figure 3 repolished, showing peripheral crack, with deformation marks removed. X 500.

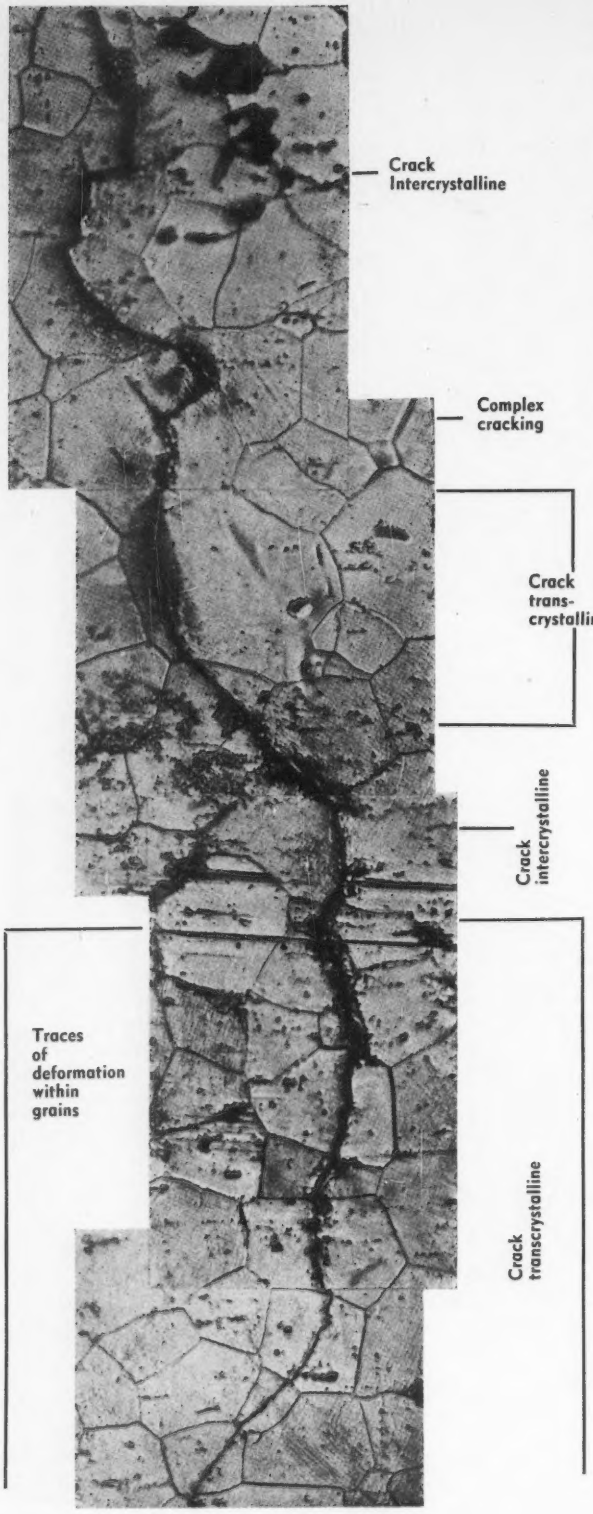


Figure 5—Specimen of Figure 4 etched in 2 percent nital, showing peripheral crack in relation to grain structure. Differing slightly from Figure 3 owing to removal of metal during repolishing. X 500.

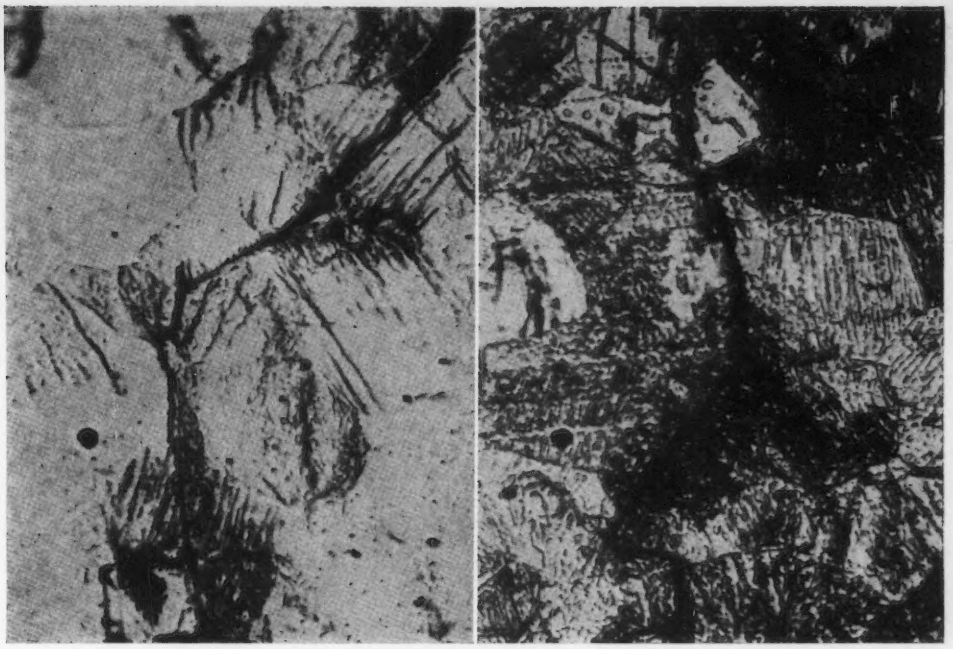
Micro-cracks—The scatter of results in fatigue testing makes it impossible to forecast the exact life of any one specimen; it also follows that any two apparently similar wires tested under the same conditions are not strictly comparable.

Specimen 1 (Table IV), which had suffered no previous fatigue, constitutes a straight tensile test of the annealed wire: failure occurred near the middle, and was of the usual cup-and-cone type. Specimens 7, 8, and 9 were taken to failure by fatigue, and micro-examination then showed the presence of 3-6 major peripheral cracks (including one which had caused failure); these cracks were distributed over a length of about 1 in. on either side of mid-span. In addition, a number of minor cracks, which passed through a few grains, were also detected (*see* Figures 7*a* and *b*); these were distributed over a length of about 3 in. on either side of mid-span. Of the remainder, specimens 2, 3, 5, and 6 showed no sign of any crack, either after the fatigue period or after tensile failure. The fracture, of cup-and-cone type, had been displaced from the middle towards one end of the wire, presumably as a result of preferential work-hardening at mid-span. The remaining specimen 4 showed a number of incipient cracks after tensile failure; the fracture, which had been initiated by one such crack, had occurred apparently by a shearing process at 45° to the wire axis. However, these cracks did not serve to lower the tensile strength of the wire.

The presence of micro-cracks in specimen 4, after a comparatively short period of fatigue, is best explained by assuming it to be a 'rogue specimen' which would shortly have failed. Neglecting this result, it seems probable that detectable micro-cracks do not occur in the surface until a late stage in the fatigue process. However, because several major cracks were discovered in wires which had failed under fatigue alone, it is fairly certain that at least some of these must have originated and spread some time before the actual failure.

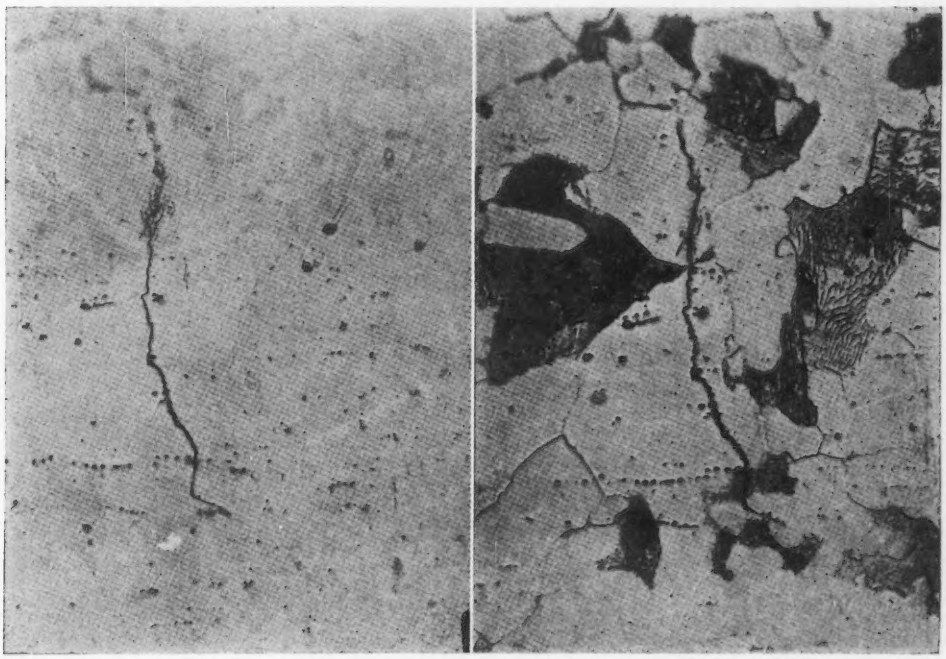
As the period of air fatigue was prolonged, the recorded values of ultimate tensile stress rose very slightly; the effect was small but is probably significant. It is clear, nevertheless, that once fatigue damage sets in, the measured U.T.S. will fall. The falling-off of elongation after air fatigue is much more definite and is, presumably, the result of work-hardening. Since the stress applied by bowing is maximal at mid-span and falls off continuously towards the ends, different parts of the wire tested will be cold worked in different degrees. The fall in elongation thus reflects the total change in properties of each part of the wire.

The photomicrographs, Figures 3, 4, and 5, show a small portion of a micro-crack in relation to the surface markings. Figure 5 shows that the path of the crack across an individual grain is often parallel to the deformation marks which accompany it. Figures 3 and 5, which refer to the same crack, also demonstrate how the crack sometimes undergoes a slight change in direction on crossing a boundary into the neighbouring grain. It is also fairly certain that the path of the crack, normally transcrystalline, may



A B

Figure 6—Electropolished specimens: A—unetched; B—etched in 2 percent nital. Air-fatigue above fatigue limit. X 700.



A B

Figure 7—Electropolished specimens: A—repolished showing minor transcrystalline crack; B—as in A but etched in 2 percent nital, showing crack passing through pearlite. Air fatigue to failure. X 700.

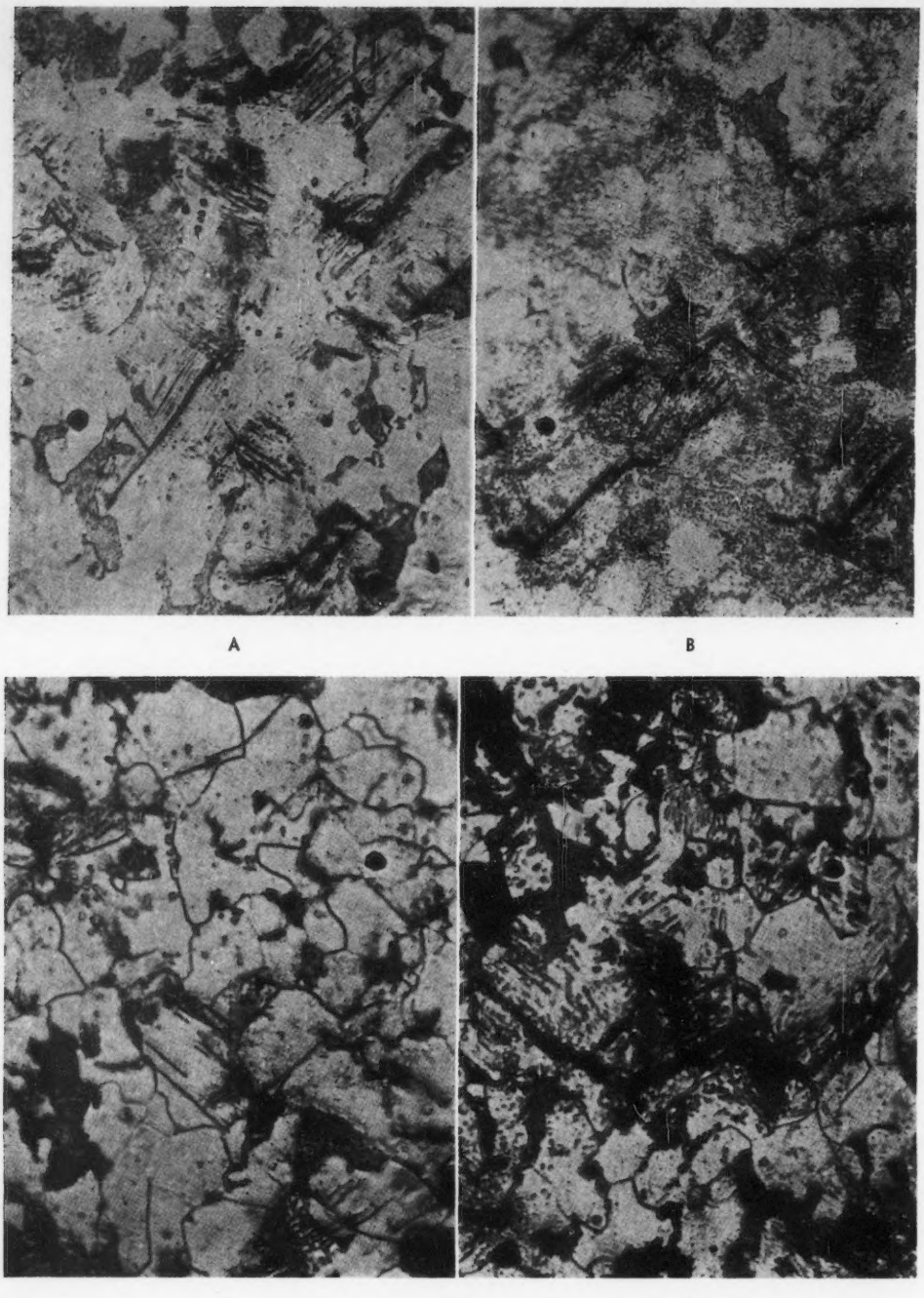


Figure 8—Micro-cracks produced in corrosion fatigue. Stress below fatigue limit, with M/100 KCl corrosive solution: A—after electropolish; B—cracks opened by tension; C—similar to A but nital eched; D—similar to B but nital etched. X 700.

occasionally follow a grain boundary, but rarely for more than one boundary, before it again becomes transcrystalline (*see* Figure 5).

The path of the crack is not always straight or even continuous across a grain, but may be serrated. Several examples of this effect are shown in Figures 2*a* and 3. With such cracks it will be noted that certain portions are again parallel to the main direction of the deformation marks; these portions are joined up by short cracks which make an angle with the main direction.

After air fatigue at a stress range below the fatigue limit, the corresponding changes, even after 25 million cycles, are very slight. Thus, little or no heating of the specimen occurs and no heat tints are developed. Micro-cracks do not develop, and the deformation marks are restricted to a very small proportion of the grains.

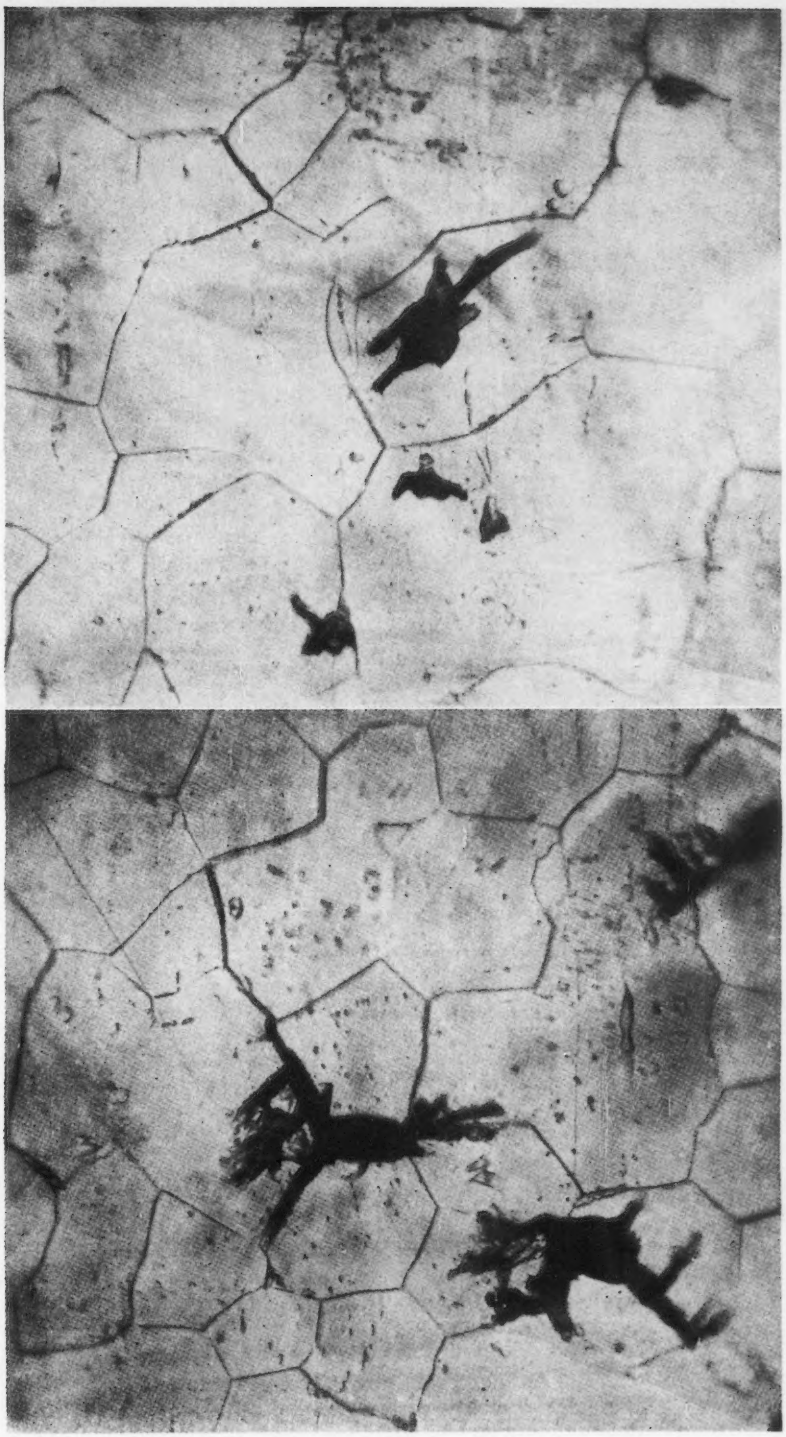


Figure 9—(top) Crack starting with grain at a corrosion pit.

Figure 10—(bottom) Crack starting at a grain boundary.

Figures 9 and 10—Origin of corrosion-fatigue cracks. Stress above air-fatigue limit, with M/100 KCl corrosive solution. Etched in 2 percent nital after corrosion fatigue. X 1500 approx.

The heating produced above the fatigue limit could probably be used as a rapid means of determining the value of that limit; it would only be necessary to run the machine for a few minutes and to touch the wire with a dissimilar metal joined through a millivoltmeter to the machine; a rise in temperature would produce a thermo-electric e.m.f.

Corrosion Fatigue Followed by Tension

A series of electropolished annealed wires were protected with polystyrene lacquer, except for a 0·5-cm. length at mid-span, and were subjected to corrosion fatigue by M/100 KCl solution for different periods; the remaining strength of each wire was then determined with a tensometer. The applied stress range of 11·8 tons/sq. in. is below the air-fatigue limit. The objects of these tests were:

(i) To determine any relation between the distribution of corrosion and any metallographic feature

(ii) To obtain a measure of the damage produced in a given specimen by its loss of strength.

The results are recorded in Table V, and are described below.

The stress was 11·8 tons/sq. in. (below air-fatigue limit); the material was annealed mild-steel wire with electropolished surface, and the corrodent was an aerated M/100 KCl solution.

Changes During Corrosion Fatigue

The increasing damage to wire specimens caused by corrosion fatigue is reflected by their loss in tensile strength, and is also confirmed by micro-examination of the corroded regions. Each wire was examined after the corrosion - fatigue period, again after failure in tension, and finally after cathodic cleaning to remove most of the adherent rust.

Specimens 1 and 2 (Table V), after a considerable period of corrosion fatigue, did not, however, fail within the corroded zone when subsequently broken in tension. The strength of both specimens was little affected, though in both cases a number of micro-cracks, of length 1-3 grains, were opened up on the corroded surface. Immediately after the corrosion-fatigue period, each

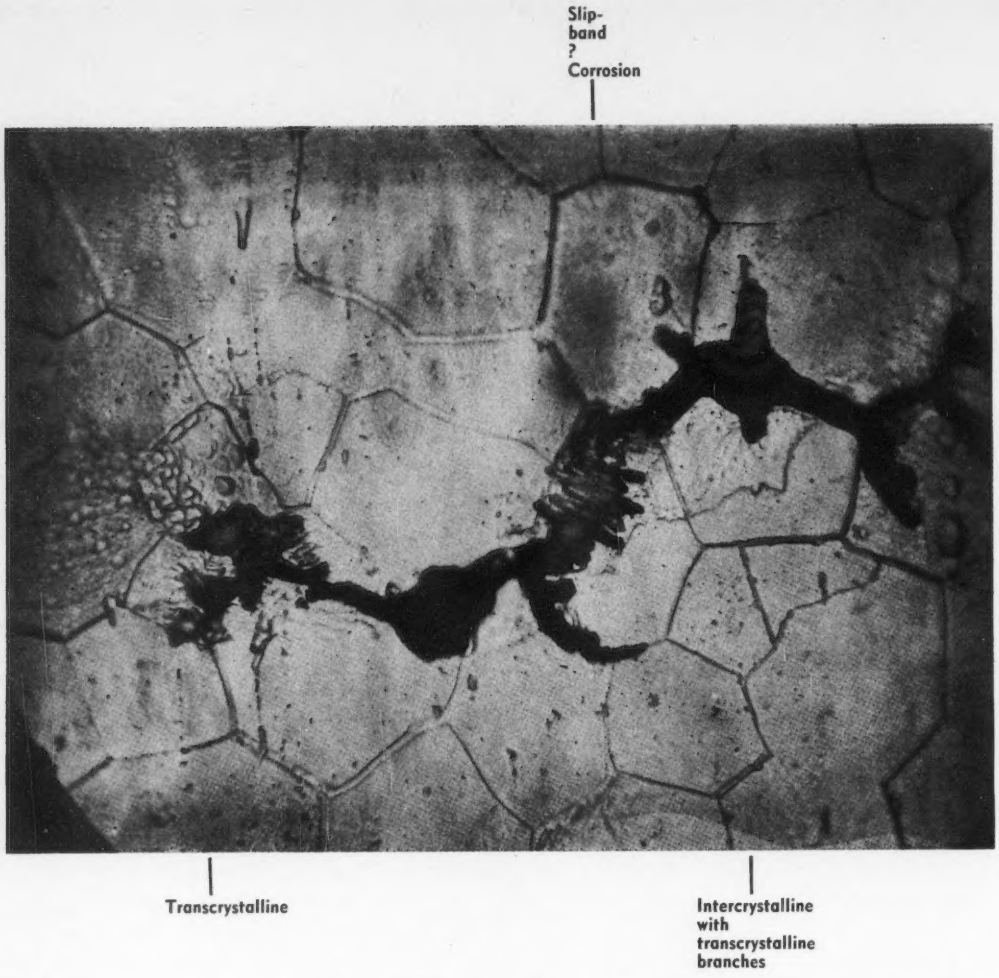


Figure 11—Early stages of corrosion-fatigue crack. Stress above air-fatigue limit with M/100 KCl corrosive solution. Etched in 2 percent nital. X 1500 approx.

wire displayed a number of small rust spots; associated with each spot a tongue-shaped region showing interference colours extended around the circumference of the wire in a direction opposite to that of rotation (*see* Figure 12). Similar colours are found under conditions of static immersion, and are commonly ascribed to hydrated ferric oxide. It would appear that such films could be produced only by precipitation of a corrosion product in intimate contact with the surface, through hydrolysis and oxidation of ferrous salts formed at anodic points (possibly helped by cathodically formed alkali), since they appear not at the place of corrosion, but on the adjacent uncorroded surface. The micro-cracks which are opened up under tensile stress are marked as fine dark lines under corrosion fatigue. Such lines are believed to be due to the combined effect of corrosion and slip deformation—the latter being induced by the stress concentration arising from the original corrosion pit.

TABLE V

Loss of Strength of Polished Annealed Wire After Corrosion Fatigue Below the Air-Fatigue Limit

Specimen No.	Reversals of Corrosion Fatigue, Kilocycles	Remaining U.T.S. Tons/Sq. In.
1	403*	32·45†
2	763*	32·45†
3	1467*	28·8
4	1483*	29·6
5	1773*	28·1
6	1919	....
7	1383	....
8	2387	....

* Specimen unbroken.
† Broke in tension, but not within corroded region.

As the period of corrosion fatigue was prolonged, the resultant corrosion did not become general but it spread around the circumference of the wire with the formation of 8 to 20 partial or complete rings of rust. Between these rings the material showed no attack, though layers of rust and interference films had been deposited there. At this stage, the tensile strength had been reduced significantly and, at the site of each rust ring, a major peripheral crack had been opened; the fracture was itself initiated at one such ring. Whenever the rust ring around the wire was not complete, the application of tension caused heavy

localized deformation at the stress concentration. Many of these effects are demonstrated diagrammatically in Figure 13.

Despite the highly localized corrosion and cracking, it is evident that the remaining strength of the wire is still considerable, even after prolonged corrosion fatigue. Therefore, the major damage, as judged by loss in tensile strength, occurs in the late stages of the corrosion-fatigue process (as in air fatigue and also in the stress corrosion of light alloys[5]).

After corrosion fatigue, the adherent rust made it difficult to discover, by microscopical examination, the exact places of attack. When it was removed by cathodic cleaning, a dark channel was visible at the site of each rust ring, into which it was impossible to focus. However, at the edges of each channel, line corrosion and/or cracks were visible, presumably the result of slip-band corrosion.

This type of highly localized attack could be distinguished more satisfactorily on the region adjacent to the exposed surface. Here, a superficial attack occurred below the lacquer, with the formation of a thin layer of rust; most of this rust could be peeled away with the lacquer layer to reveal the metal surface. Typical areas are shown in Figure 8, in which the pearlite regions have been darkened, and the ferrite grains have been etched in parts. Figure 8*b* shows the micro-cracks which have been opened under tension, and Figures 8*c* and 8*d* demonstrate respectively the occurrence of slip-band corrosion and micro-cracks in relation to the alloy structure, as developed by etching in 2% nital.

These and other observations suggest that the path of the corrosion-fatigue attack and cracking is predominantly transcrystalline; there appears to be no special tendency to avoid pearlite areas.

A few corrosion-fatigue experiments have been carried out above the fatigue limit with the object of cutting down the amount of corrosion needed for cracking. Figure 9 shows where corrosion, starting in the centre of a grain, has initiated cracking. Figure 10 shows where cracking has started on a grain boundary, probably at a place where three grains met, and is extending in an intercrystalline manner. Figure 11 shows a crack which is partly transcrystalline but partly intercrystalline, with transcrystalline branches starting from the latter portion. These three specimens were etched in 2% nital after corrosion fatigue.

Discussion

Relations Between Corrosion Fatigue and Other Forms of Failure

Intergranular Attack—If a material, containing an intergranular network more susceptible to corrosion than the substance composing the grains, is placed in a liquid just sufficiently aggressive to attack the network but to leave the rest untouched, intergranular attack may be expected. Usually, the network will provide the anodes of the corrosion cell, and the rest of the grains will provide the cathodes, so that the latter may receive additional protection, making

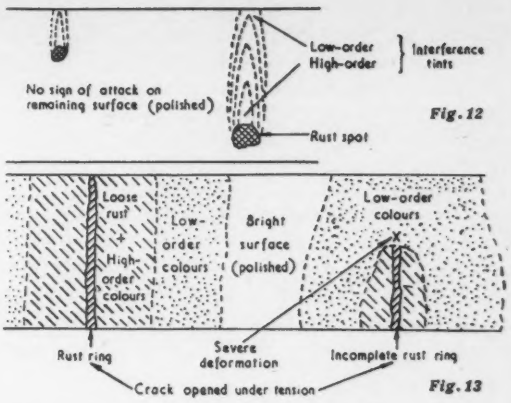


Figure 12—Appearance of wire surface after short period of corrosion fatigue. Micro-examination.

Figure 13—Appearance of wire surface after prolonged corrosion fatigue, then tension. Micro-examination.

sharper the distinction between attacked and unattacked portions. However, intergranular attack can be expected only if the chemical or electrochemical contrast between the grain interiors and grain edges is sufficiently pronounced, and if the liquid is one which can act selectively; a liquid so strongly corrosive as to produce general attack will fail to start intergranular penetration.

Stress Corrosion—Although for a given amount of metal destroyed, intergranular corrosion must produce more weakening than general corrosion, its effect on mechanical properties becomes far more pronounced if a tensile stress is applied during the attack, since the destructive effect is then concentrated on a *limited* number of grain boundaries, notably some of those running at right-angles to the stress direction. Under such conditions, the intergranular grooving produced by the corrosion may at certain points lead to a stress concentration sufficient to start cracks, which propagate themselves inwards by conjoint mechanical-chemical action. Probably the chemical attack helps the mechanical cracking by destroying any mechanically strong bridges which would otherwise hold up the advance of a crack, whilst the mechanical stress aids the chemical action proceeding at the tips of suitably orientated cracks, by rupturing chemically resistant bridges, breaking up protective films, and possibly shifting the potential in a direction favourable to anodic corrosion as a result of plastic deformation.

The occurrence of a chemically sensitive network between relatively resistant grains may come about in different ways. If an alloy be imagined to consist of two phases possessing the properties of platinum and sodium respectively, with the whole of the sodium-like phase present (as eutectic or otherwise) along the intergranular borders, forming a nearly continuous network, intergranular attack would be likely, whatever the reagent. When the contrast between the two phases is smaller, intergranular attack (and stress corrosion, which is a special form of it) is only to be expected if the liquid is just sufficiently aggres-

sive to attack the one and spare the other. It is commonly believed that the susceptibility to stress corrosion which various Al-Mg and Al-Cu alloys acquire after certain heat-treatments, is due to a network consisting of material anodic towards the main phase; in the first case, the anodic substance is believed to be the β-solid solution, whilst in the second case it is thought to be aluminium having a much lower concentration of copper in solid solution than exists in the grain interiors. Opinion is divided as to the correctness of the descriptions just suggested for the attackable phase, and lately other views have been developed, suggested by the fact that temper-hardening alloys and ageing steels appear to be specially sensitive to stress corrosion.

According to these views, the attackable substance consists of disarrayed material formed along the grain boundaries during the ageing or tempering. In ageing and hardening changes there is a passage from a supersaturated solid solution, which although unstable is likely to be accurately arrayed as regards its crystal structure, towards a state more stable in the thermodynamic sense. In changing from one crystallographic arrangement to another, the atoms must pass through intermediate states characterized by great disarray. Sometimes these intermediate states may be associated with great mechanical strength, and are then considered desirable (as in age-hardening alloys). Under other conditions, the disarrayed atoms are more quickly removable than the accurately aligned atoms (even though, thermodynamically, the intermediate product may be more stable than the material from which it is formed). Since atomic rearrangements take place most readily at grain boundaries (where the atoms affected by two orientations are less strongly held than elsewhere), it is not surprising, after certain heat-treatments, to find attack concentrated upon grain boundaries, leading to stress corrosion if a tensile stress is applied during the attack.

Stress corrosion can cause cracking to extend along any paths of low chemical and mechanical resistance which run in the right direction. As already stated, these are often intergranular in character, but sometimes, as in magnesium-base alloys, they may be transgranular. Since, however, cracking is only likely if the material has been so treated as to produce paths definitely more susceptible to attack than the main part of the material, and if the liquid is one which will act preferentially on the material of the paths, leaving the rest untouched, it follows that the stress corrosion produced by simple tensile stressing is not a very common phenomenon.

Corrosion Fatigue—In the case of corrosion cracking produced by alternating stress, almost any corrosive liquid can produce failure on almost any material, irrespective of its previous heat-treatment. This is probably because the deformation itself produces disorganized and chemically sensitive material. Even though the stress range applied is below the fatigue limit, there may be notches, cavities, or other defects which allow local plastic deformation to take place in the opening stages, as a result of stress intensification. In the absence of a corrosive substance, however, the disorganization of the material along any temporary slip bands brings about a rise in the elastic limit (work-hardening), and in due course the whole specimen subjected to alternating stress is able to undergo elastic, as opposed to plastic, deformation. If, however, a corrosive agent is present, the disarrayed material formed locally along small slip bands may be very susceptible to attack, and usually the contrast between the disarrayed and undisarrayed material will be so pronounced that the latter remains quite unattacked. Very fine cracks therefore advance inwards, by conjoint chemical-mechanical action, until the specimen breaks. It would seem that, whereas *stress corrosion* due to simple *tensile* stress requires *pre-existing* paths of chemically weak matter produced by previous heat-treatment or otherwise, *corrosion fatigue*, set up by *alternating* stresses, manufactures its disorganized sensitive matter as the crack advances. Thus the cracks follow, on the whole, the directions along which incipient or temporary gliding would be likely to produce disorganized matter.

It would also appear that the special susceptibility of the disarrayed metal is effective only if the corrosive liquid acts upon it while the atoms are "on the move" and while the metal at the tip of the advancing crack is very hot. The experimental results recorded in this paper suggest that if the displaced atoms are given time to 'settle down' and 'cool,' they cease to be specially susceptible to attack.

The explanation suggested serves to interpret the general character of the cracks shown in the photomicrographs; it is evidently an over-simplification to suggest that corrosion fatigue always produces transgranular cracking, and stress corrosion always intergranular cracking. There are places where corrosion-fatigue cracks become intergranular, and examples are known (*e.g.*, in magnesium-base alloys) where stress-corrosion cracking is transgranular. A more important distinction is that corrosion fatigue can produce damage with almost any combination of material, heat-treatment, and corrosive agent, whereas stress-corrosion cracking occurs only after certain unfortunate combinations of these three factors.

Acknowledgments

The authors wish to thank the British Iron and Steel Research Association for financial support, and the members of the Corrosion Committee of that Association for interest and encouragement.

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Topic of the Month

Figure 2—The vertical aluminum solar fins of the General Petroleum Building in Los Angeles illustrate the use of the metal for major architectural features.

Aluminum Exterior Facing For Lightweight Fire-Rated Wall Construction

By O. M. MADER

THE DEVELOPMENT of cramped cities has forced construction into the air in search of space. Pure masonry construction, not readily adaptable to multi-story buildings, gave way to the steel framed building. As a result, wall construction, supporting its own weight for only one floor height, could be lighter, thinner, and more economical. However, it is only very recently that the builder has begun to take fullest advantage of these benefits. Until a few years ago, exterior walls closing the steel frame against the elements have been almost universally of masonry types of considerably greater weight, strength and thickness than is necessary for a perfectly functional wall.

Now the search is on for lightweight wall constructions which permit savings in steel structure and foundations, provide adequate fire resistance and thermal insulation, and allow the architect new freedom in esthetics. Such constructions should be capable of rapid and low cost installation by emphasis on large erection units and preassembly.

To meet fire rating requirements of major structures, most lightweight walls continue to employ a masonry "back-up." These masonry components can be as little as 4 inches thick by use of lightweight concretes only one third the weight of conventional concrete. New methods of placing these materials in position have lowered costs. While offering excellent fire resistance and insulation, and adequate strength, the lightweight concretes are generally lacking in surface weather resistance. Thus an "armor" or "skin" to protect the back-up and beautify the facade is necessary. Aluminum castings, extrusions and sheet in large erection units are rapidly proving themselves an economical and popular answer to the "skin" problem. They offer permanence, light weight, strength, ease of fabrication and erection and a wide choice of decorative treatment.

Generally, the aluminum facings are spaced from the masonry back-up by an air void. Joint details exclude water but permit free "breathing" of the void to carry off internal moisture.

A long history of usage of aluminum for roofing, windows and many other architectural items has proved its excellent resistance, whether bare or specially finished, to the effects of varied atmospheres including seacoast and industrial. To achieve maximum performance of wall facing, consideration is given to oxide coatings for decoration and to insure maintenance of finish, to the suitable handling of dissimilar metal contacts, the localized protection of concealed dirt-trapping ledges and direct aluminum-masonry contacts. Other than these simple precautions, no further treatment of the aluminum is required in other than extreme circumstances of chemical pollution, etc.

Pictured here are the Equitable Building and the United Nations Secretariat, two current examples of aluminum exterior wall treatment. Other outstanding projects using complete facades of aluminum are the Alcoa Administration Building at Davenport, Iowa, the Bradford General Hospital at Bradford, Pa., a 24-story building at 655 Madison Avenue, New York, and a refacing job on the Commercial Building in St. Louis. Now under construction at Pittsburgh, the Alcoa Office Building will be completely faced with formed aluminum sheet. At least a dozen other major projects are in the planning stage. Scores of other buildings have utilized aluminum for major exterior architectural units including solar fins and sunshades, mullions, column covers and spandrels. Pictured here is the General Petroleum Building featuring aluminum solar fins for the total building height.

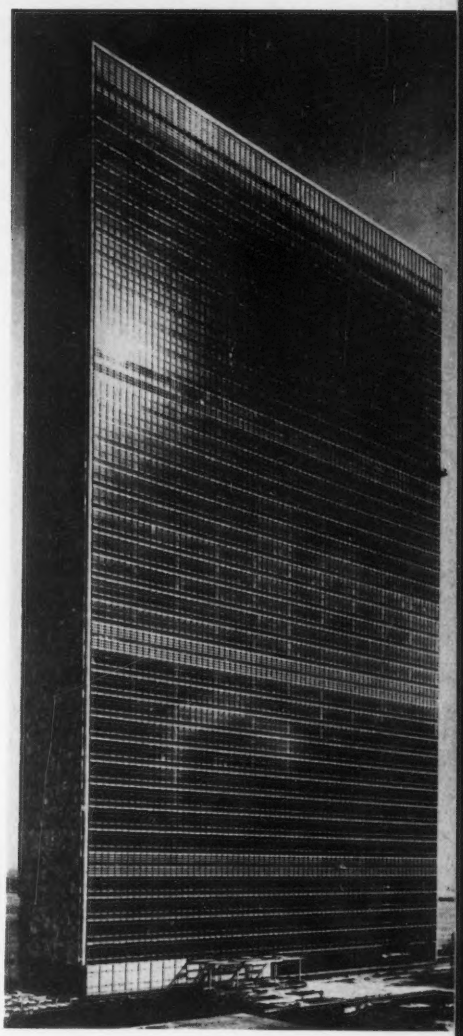

Figure 1—Only aluminum extrusions and glass are exposed to the weather on the main facades of the United Nations Secretariat in New York.

NACE News

Tulsa Section Plans Three Day Corrosion School

Hamilton Is Named North East Chairman

H. L. Hamilton, Keystone Pipe Line Co., Philadelphia, was named chairman of North East Region along with other new officers for 1951 in a letter ballot of the membership. L. B. Donovan of Consolidated Edison Co. of New York was named director to succeed Robert L. Lynch representing North East Region on the national board. Mr. Donovan's term of office begins on the last day of the 1951 conference. Other officers' terms begin on the first day of the calendar year.

Other region officers elected were: T. P. May, International Nickel Co., Inc., New York, vice-chairman; E. R. English, H. C. Price Co., Philadelphia, Pa., re-elected secretary-treasurer.

At a November 1 meeting of the region its membership was given as 740.

Effect of Extremely High Temperatures Is Explained at New York

What happens to metals and alloys when subjected to extremely high temperatures in various gases and molten solutions was explained by Dr. E. N. Skinner of The International Nickel Co., Inc., New York at a December 6 meeting of Metropolitan New York Section NACE at Building Trades Employers' Association, 2 Park Ave., New York City. Fifty-three members and guests were present.

Dr. Skinner showed that properly alloyed metals are better suited to withstand elevated temperatures than are unalloyed metals.

Section officers' election returns for the calendar year 1951, were announced at the meeting. Officers elected were W. F. Fair, Koppers Co., chairman; Kenneth H. Roll, Lead Industries Association, vice-chairman and F. J. LeFebvre, Electro Rust-Proofing Corp., secretary-treasurer.

S. D. Day Named Director

S. D. Day of S. D. Day Company, Houston, was named a director representing active membership of the National Association of Corrosion Engineers by the association's board of directors at a meeting in New York December 9 and 10. Mr. Day succeeds H. D. Murray, of Cren-Ray Plastic Products Co., Midland, Texas, resigned to enter the armed forces. Day will fill the unexpired term of Mr. Murray ending with the 1953 annual conference.

NACE CALENDAR

Jan.

8 Permian Basin Section. Gulf Oil Corp., 7 p.m. Election of officers.

9 Houston Section. Symposium on "Internal Corrosion as a Pipe Line Problem," L. G. Sharpe, Humble Oil Corp., moderator.

15 Greater St. Louis Section. Kenneth Tator (Coraopolis, Pa., "Corrosion Control and the Role of Protective Coatings."

16 Chicago Section. N. E. Berry, Servel, Inc., vice-president of NACE, "Thermogalvanic Corrosion."

16 Cleveland Section.

24 Corpus Christi Section.

30 Cincinnati Section. R. O. McDuffie Round Table discussion on Corrosion Losses. Roselawn Tavern, supper meeting.

Feb.

13 Houston Section. Joint meeting with AIChE. Speaker, Frank Whitney, Monsanto Chemical Co., St. Louis. (Meeting date subject to change.)

Holler Is Chairman Of Baltimore Section

New officers have been elected as follows by Baltimore Section NACE: Homer D. Holler, 20 Hesketh St., Chevy Chase, Md., chairman; George E. Best, Technical Service Engineer, Mutual Chemical Co. of America, Baltimore, Md., vice-chairman; Lewis G. Von Lossberg, Sheppard T. Powell, Consulting Chemical Engineer, 330 North Charles, Baltimore, Md., secretary-treasurer.

The election was announced at the November 21 section dinner meeting at Park Plaza Hotel, Baltimore, attended by 18 members and ten guests. Dr. Walter A. Patrick of Johns-Hopkins University spoke on "Studies in the Corrosion of Iron." Dr. Patrick was introduced by Paul W. Bachman, NACE director, who related Dr. Patrick's achievements in corrosion science.

Dr. Patrick described some experiments conducted under government sponsorship in which cell potential measurements were made on extremely pure iron electrodes when oxygen was excluded from the cell system. This work, soon to be reported formally in scientific circles, is expected to stimulate great interest because it is thought to point the way toward further elucidation of the basic concepts of corrosion.

Tentative plans have been made by Tulsa Section NACE for a 3-day corrosion school for pipeliners, similar to that held in February, 1950, which was attended by 178 foremen, superintendents, engineers and inspectors. Dates have been set tentatively as February 21-23, one day less than the 1950 school.

Divided equally between field work at pipeline locations near Tulsa and discussion-demonstration sessions at the Mayo Hotel, the program will be conducted again on a practical basis by pipeline men with broad experience in the mitigation of corrosion. An innovation this year will be operation of two or more classes on the same topic simultaneously in order to reduce each group to a workable number. This is expected to insure wider participation by those attending and increase benefits from the course.

Two-Fold Purpose Given

The two-fold purpose of the course, according to J. N. Hunter, Jr., general chairman, is:

1. To acquaint field men with the "why" and "how" of corrosion control so they may participate more effectively in this phase of their company's operations.

2. To acquaint corrosion engineers with various techniques for disseminating information on corrosion control to company personnel.

Emphasis will be on practical aspects of the following subjects:

Corrosion and its control, a non-technical discussion.

Rectifiers.

Coating materials and application.

Expendable anodes.

Corrosion surveys.

Use, care and handling of instruments and equipment.

Installation and testing of insulating flanges and nipples.

Committee Members Named

Mr. Hunter, general chairman, is with Service Pipe Line Co. and he will be assisted by: Hugh A. Brady, Gulf Refining Co. (field work); Yale W. Titterington, Dowell Inc. (demonstrations-discussions); Maynard H. Jackson, Middle West Coating & Supply (hotel and transportation), and T. D. Williamson, Jr., T. D. Williamson, Inc. (publicity).

Inquiries for additional information and registration forms for the short course should be addressed to J. N. Hunter, Jr., Service Pipe Line Co., Box 1979, Tulsa 2, Okla.

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Notices of meetings to be held by NACE subdivisions will be carried in the "NACE Calendar" if received in time.

Pittsburgh's Program For Seven Months Given

A seven-month schedule of meetings and topics has been outlined for Pittsburgh Section NACE by preference vote of members from 18 subjects. Some subjects were combined with others.

All meetings will be held on the first Thursday monthly, beginning at 8:15 p.m., in Room 355, Mellon Institute.

Dec. 7—Fundamentals of Corrosion, R. H. Brown, Aluminum Co. of America Research Laboratories.

Jan. 4—Fundamentals of Cathodic Protection, Keith R. Reid, Aluminum Co. of America. Use of Galvanic Anodes and of Imposed EMF in Cathodic Protection by Norman Peifer, Manufacturer's Light & Heat Co.

Feb. 1—Hot Applied Pipe Coatings, N. T. Shideler, Pittsburgh Coke & Chemical Co. Cold Applied Pipe Line Coatings by H. C. O'Brien, Jr., Royston Laboratories.

March 1—Corrosion Promoted by Organic Coatings, G. W. Seagren, Stoner-Mudge Protective Coatings Fellowship, Mellon Institute.

April 5—Inhibitors, speaker to be announced.

May 3—Theory of Oxidation, E. A. Gulbransen, Westinghouse Research Laboratories.

June 7—Application of Mathematical Statistics to Corrosion Problems, V. V. Kendall, National Tube Co.

Conference Printing Problems Are Varied

The problem of providing printing required for all purposes for a convention of more than 1000 members of a technical association are myriad, but are being ably handled for the '51 "March in New York" conference by the Printing Committee headed by George C. Hull, Jr.

G. C. Hull

Copy must be prepared and approved, and deadlines met, for programs, registration cards, abstracts, signs and numerous other items. In this, the Printing Committee has had the cooperation of the NACE Central Office at Houston.

During January, there will be mailed from Houston to every member, a copy of an advance program listing among other things technical program, exhibitors, entertainment features. This will provide full information well ahead of the actual conference dates of March 13-16.

Following this, all the information and forms required for advance registration will be mailed to members, in the hope that they will take advantage of this means of reducing the burden of registration at the start of the conference.

In the meantime, the work of printing of technical program abstracts, banquet tickets, information and directional signs has been proceeding.

Cincinnati Meeting Is Scheduled January 30

A petition will be prepared soon asking for recognition of a Cincinnati Section of the National Association of Corrosion Engineers, Lewis M. Lederer, temporary secretary of the organization reported. Decision to form a section was made at a meeting November 30, at the University of Cincinnati offices of Prof. Roy O. McDuffie at which Joseph A. Creevy presented committments from 20 members in favor of organizing a section.

A supper meeting will be held after the first of the year to which will be invited representatives of many diversified industries not now members of the association. Professor McDuffie will conduct a round table discussion on corrosion losses at the meeting.

William J. Schreiner and Milton J. Pfeiffer, NACE members of long standing were present to assist in organization of the section.

Joseph A. Creevy of Newport Steel Corp., Newport, Ky., was named temporary chairman. Mr. Lederer is with Inner Tank Lining Corp., Cincinnati.

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Reports of meetings of subdivisions of NACE should be sent to Central Office in sufficient time to meet the publication deadline of the tenth of the month preceding date of issue.

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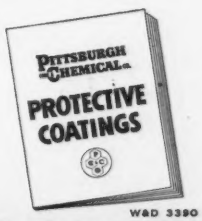

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Process Corrosion Is Discussed at St. Louis

At St. Louis Section Meeting—Joe Hercules, Hercules Construction Co.; George A. Fisher, Jr., program chairman, St. Louis Section; Everett C. Gosnell, Colonial Iron Works, St. Louis, and Frank L. Whitney, Jr., section chairman.

Numerous common sense and economical means of reducing losses from corrosion in chemical process industries were explained by Everett C. Gosnell, vice-president in charge of the Chemical and Process Equipment Division of Colonial Iron Works, Cleveland, in a talk entitled "Process Chemical Corrosion Problems and Their Solution by Selection of Materials and Design of Equipment," before St. Louis Section NACE, November 20. The dinner meeting was held at Garavelli's restaurant.

Wastage of corrosion-resistant metals by equipment failure is especially serious in these times of hard-to-get materials, Mr. Gosnell said. He stressed the economics of good design, proper materials and fabrication.

The choice of material generally hinges on the nature of the material to be handled, he asserted, while good design considerations include the use of butt instead of filet welds, elimination of corner welds and replacement of relatively heavy and costly castings by wrought and welded components. Clad metals also often make savings over solid metals, he said. Slides illustrated equipment in service.

Expanded Activity for South East Is Weighed

Expanded activity for the National Association of Corrosion Engineers in South East Region is contemplated under a program announced by J. F. Johnson, Secretary-Treasurer of the region in minutes of the region's fall session. The region, which for some time has been holding its meetings alternately in Birmingham and Atlanta, now contemplates locating the spring meeting somewhere else with the purpose of thereby initiating additional interest in the association. A mail ballot seeking a consensus on the location of the spring meeting will be taken.

The fall meeting program, November 8, included an illustrated talk by J. T. MacKenzie of the American Cast Iron Pipe Co. on "Graphitization in Cast Iron." R. J. Raudebaugh of Georgia Institute of Technology talked on "Corrosion Problems in the Textile Industry." Sidney E. Trouard of New Orleans Public Service Inc. reported on "Engineering Plans for the Application of Cathodic Protection to the Inside of Steam Plant Condenser Discharge Pipes at New Orleans." A. B. Campbell, NACE executive secretary, was dinner speaker.

Nominations were made as follows for 1951 officers: For Chairman: E. P. Tait, Alloy Steel Products Co., Atlanta, Ga. For Vice-Chairman: R. A. Davis, Chicago Bridge & Iron Company, Birmingham, Ala. For regional director: E. C. Range, Okonite Co., Atlanta, Ga., and A. R. Swanson, American Tel. & Tel. Co., Atlanta (one to be elected). For secretary-treasurer: H. C. Van Nouhuys, Southeastern Pipe Line Co., Atlanta, Ga. Membership: Jack West, Aluminum Co. of America, Atlanta, Ga. Program chairman: H. W. Dent, Jr., American Cast Iron Pipe Co., Birmingham, Ala. For by laws: E. D. McCauley, American Cast Iron Pipe Co., Birmingham, and E. C. Pritchett, American Telephone & Telegraph Co., Atlanta, Ga.

LeFebvre Coordinates Meeting Room Needs

The task of coordinating requirements for meeting room facilities at the Hotel Statler during the '51 "March in New York" Conference and Exhibition is being organized under the direction of F. J. (Lee) LeFebvre, Chairman of the Hotel and Meeting Rooms Committee.

F. J. LeFebvre

Working with the cooperation of the hotel staff, the committee is arranging for suitable meeting rooms to be available at the times needed, for use by Technical Practices Committees, Conference Committee, Association officials, etc. Some committees have not yet made known their requirements, but are urged to do so in order that suitable accommodations can be reserved at an early date.

Advance notices of meetings of organizations other than NACE engaged in corrosion work will be published on request in the "Meetings" column.

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THE LARGEST ORGANIZATION OF ITS KIND GIVING SAFE MAINTENANCE AT LOW COST

Organic Coatings Are Discussed at Western New York Meeting

A joint afternoon meeting of the newly formed Western New York Section and the North East Region at the Hotel Statler in Buffalo on November 15, was attended by 70 members and guests.

The meeting was opened by Chairman G. L. Cox, who introduced E. R. English, Secretary-Treasurer of the North East Region. Mr. English welcomed the new section to the National Association of Corrosion Engineers and commented briefly on the national meeting to be held in New York City in March.

Dr. George Segran, Research Director of Stoner-Mudge Company, Pittsburgh, Pennsylvania, spoke on "Protective Organic Coatings." He brought to the attention of the group some fresh and often overlooked ideas on protective organic coatings by pointing out that organic coatings can sometimes promote accelerated corrosion.

Corrosion promotion by organic films is generally brought about by the permeability of the film, lack of adequate adhesion resulting in lifting and lack of continuity. These conditions can cause localized and rapid corrosion.

Permeability Initiates Attack

This type of corrosion is generally of two forms: spot and filiform. Both types are generally initiated by permeability, but spot corrosion generally occurs where poor adhesion of the film is present, while filiform corrosion occurs where adhesion is good. This latter type corrosion is characterized by threadlike deposits on the substrata of hollow tubes of corrosion products, which never cross each other.

Pigmented organic coatings can also promote corrosion if not applied correctly. Examples were given of use of anti-fouling paints directly over non-primed metal. Other examples were cited where accelerated corrosion was caused by organic coatings in food jar covers and galvanic couples set up by joining coated and uncoated metals.

Dr. Segran concluded by emphasizing that the real danger resulting from organic coating corrosion promotion is that the rate of corrosion cannot be calculated and the life expectancy of the coated article cannot be estimated.

Oil Additives Outlined

Dr. A. A. O'Kelly of the Alox Corporation, Niagara Falls, New York, spoke on "Oil Addition Agents." Dr. O'Kelly pointed out that nature did an incomplete job on petroleum products as far as their use in modern machines is concerned. Man's ingenuity in making additives to correct nature's shortcomings has resulted in a $50,000,000 a year business and all signs are that it will grow rapidly.

Additives are now being used in motor oil as pour depressants, oiliness agents, detergents, anti-oxidants and rust preventives. Much of the theory on the use of the additives is incomplete at this time, but experimental work in progress should assist in the development of adequate theories. No true anti-oxidants have yet been found to eliminate all the difficulties arising from the use of high sulfur motor fuels, but apparently much of the efficiency of anti-corrosive additives is dependent on the basicity of the additive.

Examples were cited of the use of additives in high pressure lubricants, cutting oils, metal drawing oils, penetrating oils, ceramic and marine oils. In all cases additives have improved these products considerably.

The third speaker was M. A. Scheil, Director of Metallurgical Research, A. O. Smith Corporation, Milwaukee, Wisconsin. His talk was based on a number of case histories involving corrosion of stainless steel process equipment with an analysis of the failure in each case.

Cast Iron Pipe Research Laboratory Is Moved

Kirk H. Logan, research associate of the Cast Iron Pipe Research Association, has been withdrawn from the National Bureau of Standards and established in a private laboratory and office at 1845 47th Place N. W., Washington 7, D. C., where he will continue his research on underground corrosion and cathodic protection.

Waldrip to Speak at New Orleans Meeting

Harry E. Waldrip, Gulf Oil Corp., Houston, Texas, spoke on oil and gas well corrosion at a scheduled December 18 dinner meeting at the Jung Hotel, New Orleans, of the New Orleans-Baton Rouge Section. Attendance by 40 was anticipated. A question and answer session also was planned.

The section will meet regularly on the third Monday monthly, alternating between New Orleans and Baton Rouge.

Philadelphia Section's New Officers Named

New officers have been elected for 1951 by Philadelphia Section as follows: Henry F. McConomy, The Atlantic Refining Co., chairman; W. R. Briggs, W. A. Briggs Bitumen Co., vice-chairman and Frank Kahn, Philadelphia Electric Co., secretary-treasurer.

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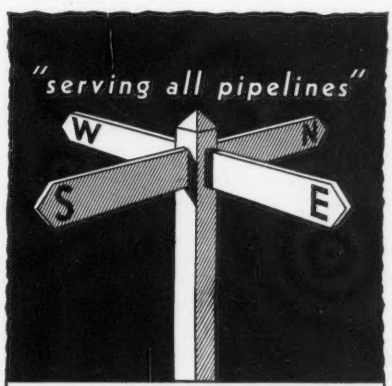
Corrosion mitigation processes and materials are publicized free of charge in CORROSION's "New Products" section. NACE accepts no responsibility for accuracy of performance claims.



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Permian Basin Section Reorganized December 6

Reorganization of the Permian Basin Section NACE, which has held no meetings since last spring was effected at a gathering December 6 at Gulf Oil Corp. office building, Odessa, Texas. Nineteen members and guests attended and heard William H. Crenshaw, Cren-Ray Plastic Products, Midland, Texas, speak on "Plastics in General." Mr. Crenshaw outlined 15 major types of plastics and main uses, characteristics and approximate volume of production of each.

Several significant decisions were reached during the business meeting:

1. The section will meet the first Monday of each month, unless the date is that of a national holiday when the date will be moved ahead or back, and the changed date announced at the meeting preceeding the holiday.

2. E. B. Ray, first vice-chairman, presiding, made the following appointments:

Aaron Gensberg, Gulf Oil Corp., Odessa, chairman of the program committee.

William H. Crenshaw, Cren-Ray Plastic Products, Midland, chairman of the membership committee.

C. O. Bundrant, The Western Company, Midland, to act as trustee of the section until an election of officers can be held January 8, 1951. This meeting probably will be held at the Gulf Oil Corp. building beginning at 7 p.m. A speaker on corrosion will be named later.

Plans were pushed for early completion of a printed report on the 1949 Corrosion Tour in West Texas. Aaron Gensberg agreed to meet with four leaders and help to get the field trip reports in printable shape.

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Five-Month Program Is Outlined for Houston

A five-month schedule of meetings has been outlined for Houston Section as follows:

January 9—A symposium meeting on the subject of "Internal Corrosion as a Pipe Line Problem." L. G. Sharpe of Humble Pipe Line Company will act as moderator.

February 13—A joint meeting with Houston Chapter of the American Institute of Chemical Engineers. The principal speaker will be Frank Whitney of Monsanto Chemical Co., St. Louis. Mr. Whitney is head of Monsanto's corrosion engineering department. A visit to the Sheffield Steel Corp. plant also is scheduled. This meeting date is subject to change.

March 13—A program on coatings is being prepared by George Holm of Tubekote.

April 5—Graduating students of the University of Houston, Rice Institute, Texas A & M and the University of Texas who are interested in corrosion will be invited to attend. The speaker will be R. B. Mears of Carnegie-Illinois Steel Corp. whose subject will be "The Role of the Corrosion Engineer in Industry."

May 8—F. L. LaQue, head of the Corrosion Engineering Section of The International Nickel Co., Inc., will speak on "The Effects of Alloying Elements on the Corrodibility of Iron."

In addition to the main speakers listed there will be a coffee speaker at each meeting, to be named later.

An exceptionally long discussion followed presentation of a slide-illustrated lecture, "New Grades of Stainless Steel," by John J. Halbig, Armco Steel Corp., Middletown, Ohio, at the December 4 meeting of Houston Section NACE and the local Texas Chapter of the American Society for Metals. Mr. Halbig discussed five new grades of stainless, tests to which they were subjected, and corrosive conditions for which they were suited best.

Total attendance was 88 of whom 43 were NACE members and guests.

Portable Abrasion Tester Is Perfected by NBS

A portable yet highly dependable abrasion resistance tester has been developed by the National Bureau of Standards in cooperation with W. C. Clark of the General Services Administration to test floor tile before it is laid. The machine consists of a notched wheel mounted on an overhanging frame so a definite and constant weight will bear on the specimen as the wheel is turned. The tester is designed to provide for a steady flow of No. 60 artificial corundum between the wheel and the specimen which is mounted on an incline.

Details Are Given of Advance Registration For March in New York Conference by Kulman

The following information about the advance registration arrangements which will be in effect for the Seventh Annual Conference and Exhibition of the National Association of Corrosion Engineers, March 13-16, 1951 at Hotel Statler, New York City, has been given by Frank Kulman, chairman of the Registration Committee for the conference:

When to register: A registration form is being mailed to each NACE member early in January. This form should be filled in and mailed, with the required registration fee, before March 2, to the Central Office in Houston.

Registration fees: Members who are registered in advance and who do not attend the conference will be refunded the full amount of their fee if application is made to NACE Central Office before April 16.

Non-members who have paid the $7.50 charge and who subsequently join NACE will receive $2.50 toward their first year's dues, provided the membership application is received at NACE Central Office before April 16.

No refunds will be made after April 16.

Advantages of pre-registration: Members registering in advance will avoid the inconvenience of waiting in line to register at the conference. Pre-registration will allow the members to spend their time more profitably in meetings, exhibits and visiting. It will reduce the burden on the registration committee on the opening day of the conference.

Ladies' registration: In view of the interesting program planned for the ladies and described elsewhere in CORROSION, it is hoped that many of the ladies accompanying NACE members will register in advance.

Details of pre-registration: The Local Registration Committee on receiving advance registration form (before March 2), will prepare the member's badge, program and guest ticket, and enclose these in an envelope which will be identified with the member's name. The registration form will be receipted and returned by mail to the member. The member, on arrival at the Hotel Statler, will present the receipted form at the "Desk for *Advance* NACE Registration" and receive his prepared registration package.

Exhibitors' representatives: One representative of each exhibitor, to be designated by the exhibitor, will be registered without charge. The other representatives will be charged the regular fees.

Room reservations at hotel: Applications for rooms at the hotel should be made directly to the hotel at which accommodations are desired. To facilitate these reservations a postcard reservation form is being sent all NACE members, together with the Conference Registration form.

Guest tickets: On Friday, March 16, members and exhibitors will be permitted to invite guests, without charge, to the conference and exhibits. For this purpose, each registrant will receive in his registration packet a "Guest Ticket," which, upon being endorsed by registrant will permit his guest to visit the conference March 16.

Registration during conference: For those members who cannot register in advance, the customary facilities will be provided for registering during the conference. An adequate staff of registration clerks and a cashier will be on hand each day of the conference for the preparation and issuance of badges, programs, etc. The charges for registration at the conference will be the same as for pre-registration.

Expected attendance: Advance indications from the various regions and sections indicate a record attendnace of approximately 1200 and a great increase in attendance of ladies. With the cooperation of our members these will be registered with minimum inconvenience and delay.

Spectrographers to Hold Symposium in May 1951

The American Association of Spectrographers will hold a symposium on the "Use of Spectroscopy in the Steel Industry" in Chicago, during May, 1951.

Papers from members and non-members on any phase of the subject are invited. Titles and contributions should be in the hands of the Chairman of the Symposium Committee, Ralph H. Steinberg, 9531 Avalon Ave., Chicago 28, Ill., as soon as possible.

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News about the activities of organizations anywhere in the world engaged in corrosion mitigation are welcomed for use in the news section of CORROSION.

Chilton Heads AIChE

Thomas H. Chilton, technical director of the development engineering division of E. I. du Pont de Nemours & Co., has been elected president of the American Institute of Chemical Engineers for 1951.

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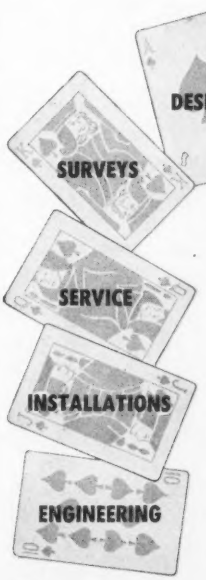

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Conference Arrangements Are Nearly Completed

In the absence of Chairman H. L. Hamilton, recently assigned to temporary duties in Venezuela, reports from Local Arrangements Committee members were heard by L. B. Donovan, at a meeting held at the Hotel Statler, New York City, on December 1.

It was reported by wire from Dr. Norman Hackerman that the Technical Program was about complete and that abstracts of papers to be presented were being prepared for publication.

G. E. Seidel wired from Chicago that applications for the last few available exhibit spaces were being processed.

Mr. Donovan, chairman of the General Conference Committee, approved the procedure to be used for advance registration, under which all necessary information and forms will be mailed direct to every NACE member on January 15, providing adequate time for return prior to the conference dates of March 13-16.

The printing committee was authorized to prepare the advance program to contain the technical program, list of exhibitors, entertainment features, etc.; mailing is to be made from Houston early in January.

Mrs. Beatrice Bailey presented a tentative schedule for the ladies' program including a get-together brunch on Monday, March 12; a trip to the United Nations meeting at Lake Success, a tea and fashion show, a visit to a trans-Atlantic liner, and other entertaining and informative trips to be arranged as desired. The Ladies Lounge will be the meeting place and center of all such activities.

Mr. Donovan expressed satisfaction with the progress being made, and advised that the February issue of CORROSION will be a special Conference issue, in which all features of the conference and exhibition will be presented in full detail.

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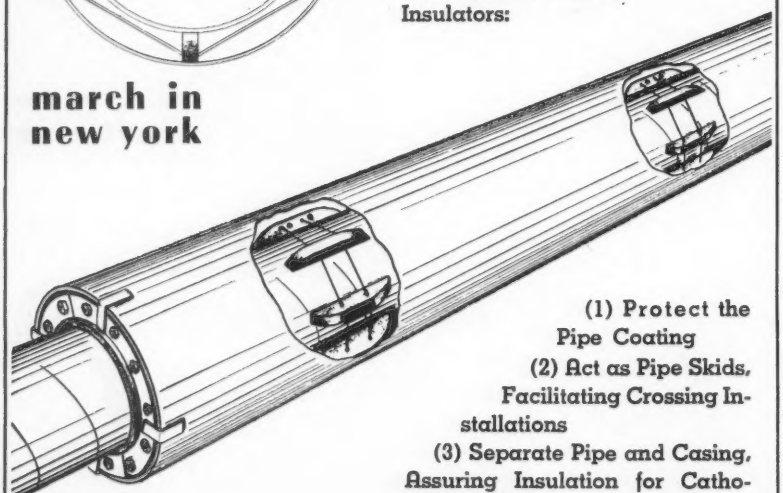

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TP-1 Members Believe Longer Meetings Needed

Members of Technical Practices Committee 1 feel the meetings of the Committee are too short and it is suggested in a report by H. E. Waldrip, committee vice-chairman, dealing with the committee's meeting during the October South Central Regional gathering in Houston, that it may be desirable to schedule a full day's meeting for the committee in the future.

The 29 members and guests present at the Houston meeting learned H. D. Murray, chairman of subcommittee TP-1D, has entered military service. J. A. Caldwell, Humble Oil & Ref. Co., Houston, was named chairman of the committee in his place and R. L. Elkins, Shell Oil Co., Great Bend, Kan., was named to assist him.

Sub-committee chairmen reported on activities of their groups. W. F. Rogers, chairman of sub-committee TP-1E held a half day symposium on Galvanic Corrosion in Oil Wells instead of reporting at the meeting. Sub-committee TP-1C under Mr. H. L. Billhartz, Atlantic Refining Co., Dallas, Texas, took as its first project a study of high-pressure, high gas-oil ratio sweet oil wells. This will be the subject of a paper by Mr. Billhartz at the national conference in New York in March. As a second problem, an investigation of corrosion in gas lift sweet oil wells has been initiated.

Annual Directory Will Be Published in March

The annual directory of members of the National Association of Corrosion Engineers will be published in the March, 1951, issue this year. Formerly the directory has been published as a part of CORROSION in the January issue The change was made to take advantage of the opportunity to publish a directory incorporating the changes made known to Central Office NACE concurrently with payment of dues during the first month of the year. Previously a large number of changes became known only after January 1 and had to be published as corrections to the directory.

In all respects other than the time of publication it is expected the directory will be the same as that published in 1950.

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Advance notices of meetings of corrosion interest should be sent to CORROSION in sufficient time to permit publication in an issue distributed before the meetings are held.

Members Are Sought for Cable Corrosion Group

Irwin C. Dietze, chairman of TP-16—Electrolysis and Corrosion of Cable Sheaths has issued letters inviting 95 prospective members to participate in the deliberations of his committee, which has its inquiries divided into six subdivisions. A general meeting of the committee has been scheduled at 9 a.m. March 12, 1951, at the Statler Hotel, New York City, on the day preceeding official opening of the 1951 NACE Conference.

Mr. Dietze has suggested in his letter that those who do not wish to participate in some of the inquiries of the committee subdivisions may prefer to be members of the general committee and thereby keep aware of what is being learned.

The scope and title of each subdivision has been outlined by Mr. Dietze as follows:

TP-16—Scope of committee: To collect, compile, investigate and develop technical data on electrolysis and corrosion of lead and other types of cable sheaths, and make this information available to all members concerned with these problems.

Subcommittees:

TP-16A—Stray Railway Current Electrolysis. Scope: To collect and compile methods of cable bonding, drainage to railway sub-stations, booster drainage, reverse current switches, insulating joints, bonding to other utilities, etc.

TP-16B—Corrosion of Lead and Other Sheaths. Scope: To investigate and develop technical information on the causes of corrosion on underground cables such as stray current electrolysis, AC electrolysis, galvanic potentials, environment and biological influences.

TP-16C—Cathodic Protection of Cable Sheaths. Scope: To investigate and develop methods of application, types of rectifiers and anodes, permissible current density, galvanic anodes, sheath grounding cells, etc.; collaborate with TP-4—Minimum Current Requirements for Cathodic Protection.

TP-16D—Tests and Surveys. Scope: To study and develop methods of conducting surveys on cable sheaths; to investigate and recommend use of various types of electrodes and instruments; development of new instruments especially applicable to cable sheaths. Collaborate with Committee TP-14—Instruments for Corrosion Measurements and the AGA Committee on Instruments.

TP-16E—Corrosion & Protection of Pipe Type Cables. Scope: To study types of coatings, testing methods, grounding and bonding, drainage and cathodic protection. Collaborate with Committee TP-6D — Protective Pipe Coatings.

TP-16F—Non-Metallic Sheath Coatings. Scope: To investigate and compile technical data on non-metallic sheaths for underground cables.

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Photographs showing interesting corrosion problems, conditions or solutions of corrosion problems are welcomed for consideration as subjects for the cover illustration of CORROSION magazine. Photographs submitted should be accompanied by an adequate description and the necessary authority to use the photograph.

CORROSION DIRECTORY

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Dedication at INCO Testing Station Is Attended by Over 100

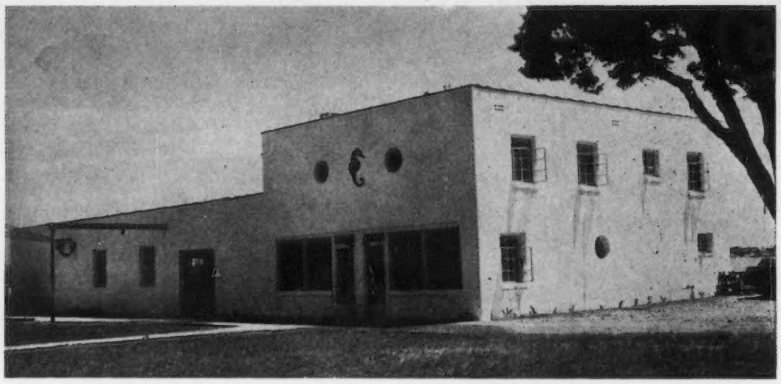
More than 100 were guests of the International Nickel Company, November 15-16, 1950, for the dedication ceremonies of the Harbor Island Test Station at Wrightsville Beach, North Carolina. This program provided an opportunity for sponsoring organizations and individuals to examine the new facilities.

The sea water corrosion testing station at Kure Beach* was started in 1935 and has expanded rather rapidly during the succeeding years. The sea water testing was done in the abandoned Dow Chemical Company power house and water intake basin. Storms destroyed the jetties protecting this location and it became increasingly difficult to maintain the facilities. Early in 1950 the decision was made to build the Harbor Island Test Station, which is located between the mainland and Wrightsville Beach. The ceremonies on November 15-16 celebrated the completion of the test station and removal of specimens from Kure Beach.

Guests spent the first day inspecting the facilities at Harbor Island and attending the official dedication at the Cape Fear Club in the evening. With complete machine shop and laboratory, almost any type of specimen can be prepared and almost any type of test that involves sea water can be run. The layout of the new laboratory permits a larger number and variety of tests than could be handled at Kure Beach. A well organized museum of corrosion specimens occupies one room of the building. A small conference room is also provided. Guests were impressed by the fact that almost every part of construction such as, piling, represent experiments in material and method of construction and protection.

The second day was spent inspecting the atmospheric test lots at Kure Beach where a large number of specimens are exposed at 80 and 800 feet from the water.

This testing program, sponsored by the International Nickel Company, is a cooperative effort. More than 100 producers and users of material and coatings have taken advantage of the facilities provided.



Above is a view of the laboratory building at the new International Nickel Co., Inc., Harbor Island testing station. More space and improved facilities for tests are featured.

* CORROSION, 1, No. 4, 178-186 (1945) Dec.; *Ibid.*, 5, No. 9, 303-307 (1949) Sept.

Instrument Society

The Houston Section Committee of the Instrument Society of America met at Houston October 10 to discuss plans for the Sixth National Instrument Conference and Exhibit to be held at Sam Houston Coliseum, Houston, September 10-14, 1951.

march in new york

- . . . The largest and most comprehensive exhibit of materials and apparatus in N.A.C.E. history.
- . . . A fascinating program for the ladies includes attending a United Nations meeting at Lake Success, a visit and tea aboard a Trans-Atlantic liner, a fashion show and other entertaining features.
- . . . And a main conference program packed with subjects of critical importance discussed by outstanding experts and leaders in the industry.

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1951 CONFERENCE AND EXHIBITION

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

HOTEL STATLER • MARCH 13 • 14 • 15 • 16

Biological Corrosion Is Discussed at Symposium

THIRD ANNUAL VARNISH AND PAINT CHEMISTRY SYMPOSIUM—Participants in the afternoon session of the symposium held November 18 at New York University College of Engineering, left to right: A. J. Liebman, Dravo Corp., Pitsburgh, Pa.; A. W. Van Heuckeroth, Corps of Engineers, Fort Belvoir, Va.; Dr. Max Kronstein, New York University College of Engineering; Dr. G. W. Oxley, Standard Oil Development Co., Linden, N. J.; F. E. Kulman, Consolidated Edison Co., New York; Dr. A. C. Elm, New Jersey Zinc Co., Palmerton, Pa.; Dr. Thomas P. May, International Nickel Corp.; V. A. Veit, Consolidated Edison Co., New York; Dr. Allen Alexander, U. S. Navy Research Laboratories, Washington, D. C., moderator of the afternon meeting.

Of the many compounds tested to limit destruction of paint by fungus the phenyl mercurials, chlorinated phenols and cooper 8—quinolinolate have been found most effective, it was reported in a paper by Richard E. Vicklund and Milton Manowitz, Engineer Research and Development Laboratories, before the Third Annual Varnish and Paint Chemistry Symposium held November 18 at New York University College of Engineering. The researchers reported the fungi once believed to be most prevalent on painted surfaces were Aspergillae and Penicillia, but recent studies in New Jersey, Florida and Texas show that while these organism frequently are found, genus Pullularia is the most frequently occurring fungus on paints.

F. E. Kulman, Consolidated Edison Co. of New York, reported on coatings for underground cables and pipes, describing coating practices current on these structures of his firm. V. A. Veit, also with Consolidated Edison, spoke on "Protective Coatings for Submersible Type Transformers and Network Protectors." He outlined experience of his company with various coatings, described apparatus, exposures encountered and cases of coating failure. Repainting of apparatus by the flow method is described.

Several other papers also were delivered.

Classified Advertising Offered in Corrosion

Decisions reached at the August 5 meeting of the National Association of Corrosion Engineers' executive committee have made available free advertising in Corrosion magazine under the headings: Positions Wanted and Positions Available.

Active members may use two consecutive insertions yearly consisting of not more than 35 words set in the standard text type.

Corporate members may use an unlimited number of advertisements consisting of not more than 35 words set in standard text type.

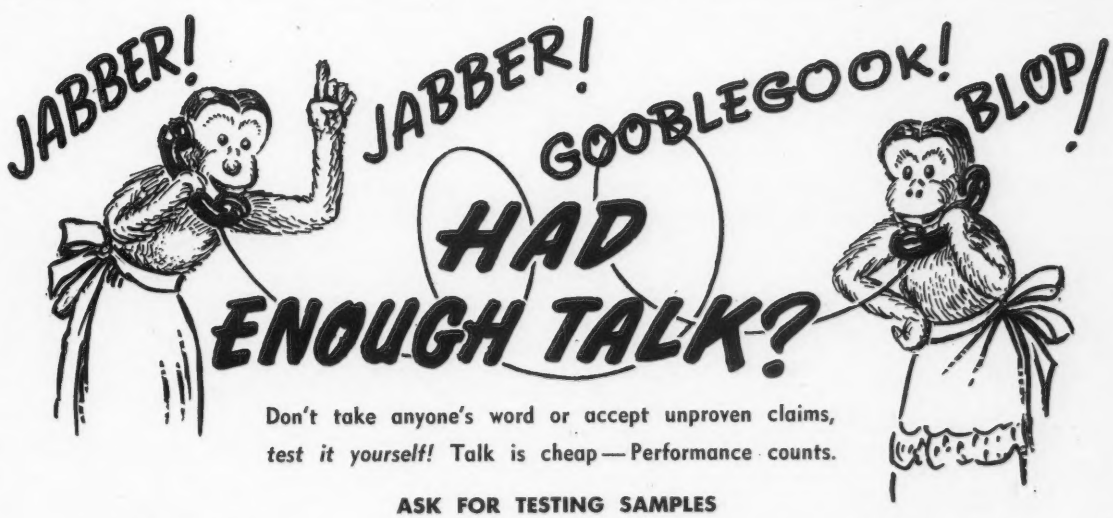
Firms not members but eligible to become corporate members also may use an unlimited number of advertisements consisting of not more than 35 words set in the standard text type.

Individual persons, not members, are not entitled to free advertising on any basis.

Advertisements of any nature or size or frequency which are different from or in excess of 35 words set in standard text type will be charged for at an appropriate rate, the minimum charge being $5.00.

•

Persons wishing to submit answers to questions asked under the column heading "Corrosion Problems" are requested to send duplicate copies of their answers to Central Office, NACE, 919 Milam Building, Houston 2, Texas. Names of persons submitting replies will be omitted on request.



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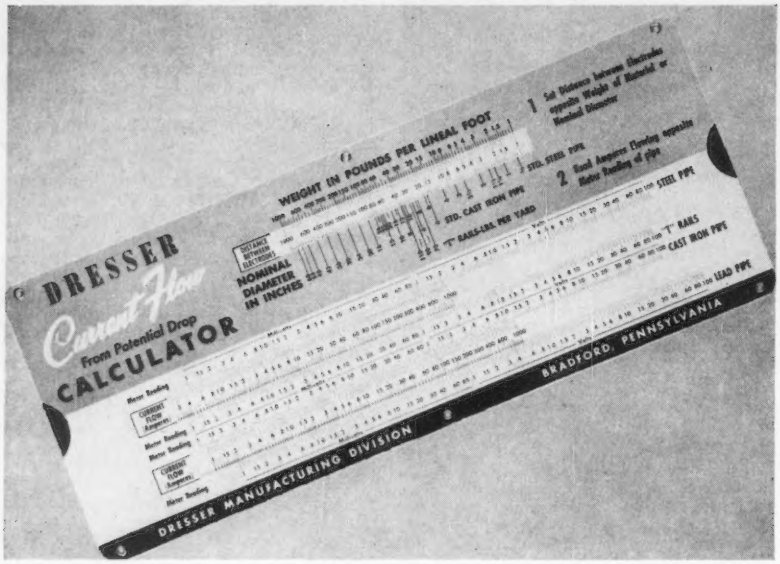
SERVICE ENGINEERS, INC.

Manufacturers of Industrial Plastic Products

FIRST NATIONAL BANK BLDG. FORT WORTH, TEXAS

Current Flow Calculator Offered by Dresser



A slide-rule "Current Flow Calculator" which will give current flow from potential-drop readings on steel, cast iron, lead pipe and T-rails has been developed by Paul F. Marx, Corrosion Engineeer, Dresser Manufacturing Division, Bradford, Pa. A calculator will be sent by Dresser free of charge to any corrosion engineer with a gas utility or pipe line company upon request written on company stationery. The address: Mr. Paul F. Marx, Dresser Manufacturing Division, Bradford, Pa.

The calculator is sufficiently accurate to use while making electrolysis surveys in the field. It will be of considerable help to the corrosion engineer by eliminating the need for detailed calculation and reference to data on different pipe structures which is unavailable in the field.

For example, if a 4-inch nominal diameter steel pipe (4½-inch OD) is under test and the electrodes or test leads are 75 feet apart and the meter reading is 6 millivolts, then to obtain the amount of current flowing on this pipe, it is only necessary to set the distance between electrodes of 75 feet, over 4-inch standard steel pipe, then directly under 6 millivolts on the steel pipe scale may be read the answer of 4 amperes flowing on the pipe.

To cite another example, the electrodes are placed 40 feet apart on 80-lb. per yard T-rails and the meter reads one millivolt. The 75 feet is set over 80 on T-rails pounds per yard and directly over 1 millivolt on the T-rail scale may be read 2.2 amperes, which is the amount of current flowing on the rails at that time.

NACE

NEW MEMBERS

AND ADDRESS CHANGES

NEW MEMBERS

(Changes Through November 27, 1950)

ALABAMA

HONKALA, H. E., Wolverine Tube Div., Calumet & Hecla Consol. Copper Co., Decatur, Ala.

CALIFORNIA

NOSS, OSCAR F., JR., 1222 East 1st St., Long Beach 2, Cal.

ILLINOIS

CAVENEY, JACK E., 7460 S. Parnell Ave., Chicago 21, Ill.

LOUISIANA

BARNETTE, B. C., JR., Electrical Engineer, Union Sulphur & Oil Corp., Sulphur, La.

ROOT, WESLEY B., JR., Esso Standard Oil Co., Louisiana Div., North Baton Rouge, La.

MISSOURI

DREWELOW, EARL, The Empire District Electric Co., 6th & Joplin Sts., Joplin, Mo.

NEBRASKA

PEARD, JAMES C., Service Pipe Line Co., Box 591, Scottsbluff, Neb.

NEW YORK

McELROY, CHARLES R., Metal-Cladding, Inc., 128 Lakeview Ave., Buffalo 1, N. Y.

WILLIAMS, FRANK L., Consolidated Edison Co. of N. Y., Inc., 708 1st Ave., New York 17, N. Y.

OHIO

GREBER, A. C., Schenley Distillers, Inc., 26 East Sixth St., Cincinnati 2, Ohio.

ROMELL, ROBERT F., The Vulcan Copper & Supply Co., 120 Sycamore St., Cincinnati 2, Ohio.

TEXAS

DEERING, ROBERT G., Corrosion Dept., Sun Pipe Line Co., Box 2831, Beaumont, Texas.

WISCONSIN

HAYNER, DONALD L., Milwaukee Gas Light Co., 626 E. Wisconsin Ave., Milwaukee 2, Wis.

FOREIGN

BONSTOW, THOMAS L., Council of British Manufacturers of Petroleum Equip., 79 Buckingham Palace Road, London, S. W. 1, UK, England.

CHANGES OF ADDRESS

(Old address follows new address in parenthesis)

ALABAMA

BAMMEL, CHARLES A., M/SGT., 38756139, H & S Co., 432nd Engr. Constr. Bn., Camp Rucker, Alabama (BAMMELL, CHARLES A., 1808 Colquitt, Houston 6, Texas).

CALIFORNIA

KRCH, MILFORD F., QMQ, U. S. Naval Station, Division 201, San Diego 36, California (KRCH, MILFORD F., National Lead Co., Baroid Sales Div., City National Bank Bldg., Houston, Texas).

FLORIDA

WHITMORE, CLIFTON W., Whitmore Electric Co., P. O. Drawer 5140, Miami, Florida (Whitmore Electric Co., Suite 806, Langford Bldg., Miami 29, Florida).

ILLINOIS

DEBEERS, FRANKLIN M., JR., 930 Surrey Lane, Glen View, Illinois (2343 Ridge Ave., Evanston, Illinois).

MOORMAN, EARL F., Research Chemist, Eng. Matls. Res. & Test Lab., International Harvester Co., 2626 W. 31st Blvd., Chicago, Illinois (Eng. Matls. Res. & Test. Lab., Farm Trac. Eng. Dept., International Harvester Co., 2626 W. 31st Blvd., Chicago, Illinois).

MISSOURI

YATES, CLARENCE C., Southwestern Bell Telephone Co., 200 North 11th St., St. Louis 1, Missouri (Southwestern Bell Telephone Co., 1509 Telephone Bldg., Kansas City 6, Missouri).

NEW JERSEY

PRIOR, JOSEPH E., S. McCarthy Ave., Mantua, New Jersey (73 N. Evergreen Ave., Woodbury, New Jersey).

NEW YORK

KAHN, WALTER C., JR., 1000 Park Ave., New York 18, New York (New York Testing Labs., 80 Washington, New York 6, New York).

KLEIN, FRED M., Maurice A. Knight Co., 130 West 42nd St., New York 18, New York (Maurice A. Knight Co., 55 West 42nd St., New York 18, New York).

RIMBAULT, E. L., JR., Federated Metals Div., American Smelting & Refg. Co., 120 Broadway, New York 5, New York (Federated Metals Div., American Smelting & Refg. Co., Box 471, Whiting, Indiana).

WHITING, L. R., Bakelite Div., Union Carbide & Carbon Corp., 30 East 42nd St., New York 17, New York (Bakelite Corp., 30 East 42nd St., New York 17, New York).

OHIO

SIMS, CHESTER T., 180 E. Lakeview Ave., Columbus 2, Ohio (1490 Arlington Ave., Marble Cliff, Columbus 12, Ohio).

TROUPE, RALPH A., 590 Diagonal Rd., Akron, Ohio (2826 Stevens St., Camden, New Jersey).

UNDERWOOD, O. G., 429 Forrer Blvd., Dayton, Ohio (6751 Oglesby Ave., Chicago 49, Illinois).

OKLAHOMA

SIDWELL, C. V., Sidwell Engineering Co., P. O. Box 4037, Tulsa 9, Oklahoma (P. O. Box 4037, Tulsa 9, Oklahoma).

STEWART, W. FRED, 703 S. Richmond, Tulsa, Oklahoma (Anode Engineering Co., 703 S. Richmond, P. O. Box 3355, Tulsa, Oklahoma).

PENNSYLVANIA

KOPETZ, GEO. E., Chem. Plants Div., Attn. Librarian, Blaw-Knox Constr., P. O. Box 778, Pittsburgh 30, Pennsylvania (Vice President, Chem. Plants Div., Attn. Librarian, Blaw-Knox Constr., 321 Penn Ave., Pittsburgh 22, Pennsylvania).

MULLIN, GROVER E., Dowell Incorporated, Rm. 1305 Morris Bldg., 1421 Chestnut St., Philadelphia 2, Pennsylvania (Dowell Incorporated, 1416 Girard Trust Co. Bldg., Philadelphia 2, Pennsylvania).

PAIGE, HENRY, Bldg. 601-N.A.M.C., Surface Treatment and Corrosion Lab., Navy Yard, Philadelphia 12, Pennsylvania (576 East 91st St., Brooklyn 12, New York).

TEXAS

BOYCE, TREVOR G., 10421 N. Oswego St., Houston 15, Texas (P. O. Box 6632, Houston 5, Texas).

KINLEY, JOHN C., M. M. Kinley Co., P. O. Box 13204, Houston 19, Texas (M. M. Kinley Co., P. O. Box 13131, Houston 19, Texas).

McCALL, RICHARD H., The Texas Co., P. O. Box 2332, Houston 1, Texas (The Texas Co., P. O. Box 72, Liberty, Texas).

McGARY, S. U., 1513 Woodcrest, Houston 18, Texas (854 West 43rd St., Houston, Texas.

Clippings on Corrosion

Extracted from Current Periodicals

WICHITAS PROSPECTED FOR TITANIUM ORE
(From Lawton, Okla. Constitution, Aug. 30, 1950)

Gerald Chase, survey geologist is prospecting the Wichita Mountains seeking a commercial source of titanium ore.

•

INHIBITOR FOR HOME WATER SYSTEMS LISTED
(From Kansas City, Mo. Weekly Star, Oct. 4, 1950)

Sudbury Laboratory, South Sudbury, Mass., manufactures an "Aqua-Clear" feeder and crystals capable of preventing rust and corrosion in water pipes and of neutralizing acids so standard soaps sud better regardless of how hard the water is. A budget of 50 cents monthly is reputed to supply a month's supply of crystals for the unit which generally is installed at the intake to the hot water tank.

•

GLIDDEN DESCRIBES NEW SILICONE ENAMEL
(From American Metal Market, N.Y.C. Oct. 21, 1950)

Cleveland—Dr. C. D. Moore, director of research of the Glidden Company's Chicago laboratory demonstrated qualities of a silicone resin enamel at the company's research conference here last week. Dr. Moore said the company considered the enamel the biggest step in the production of industrial finishes from silicones so far accomplished. The aim, he said, was to produce an enamel with the surface hardness and chemical resistance of porcelain without its brittleness.

The new material is resistant to strong corrosives and dyes and while it is not as heat resistant as porcelain enamels on pots and pans, it will withstand higher temperatures than organic finishes.

•

NORTH TEXAS SECTION NACE MEETING IS HELD
(From Ft. Worth, Texas Evening Star-Telegram, Sept. 27, 1950)

North Texas Section of the National Association of Corrosion Engineers had members of the Petroleum Engineers Club of Fort Worth as its guests Monday night at the plastic products factory of Service Engineers, Inc.

•

LEAD-COATING METHOD FOR COPPER EXPLAINED
(From Rome, N. Y., Sentinel, Oct. 10, 1950)

Washington—Wilson Lynes, Westerville and Richard H. Jenks, Sauquoit have been granted a patent on a method of coating copper with lead. It has been assigned to Revere Copper and Brass, Inc.

The inventors overcome previous difficulties experienced in coating copper

(Continued on Page 14)

Helpful Guides To
the selection of
acid-alkali-
solvent proof
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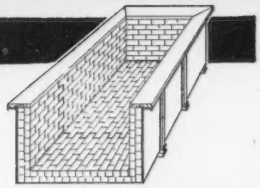
CORROSION PROOF LININGS

There is an Atlas Corrosion Proof Lining to solve every corrosion problem. Atlas Linings are based on many different plastics as well as natural and synthetic rubber. Installed at Atlas or customers plant.



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Each Atlas Corrosion Proof Cement has physical and chemical properties best suited for specific applications. Consult Atlas Technical Service to insure usage of the most durable and economical cement.

PROTECTIVE COATINGS

Atlas offers a complete line of Corrosion Proof Protective Coatings. The recommendations of a coating most suitable for customers application is a regular Atlas Service.

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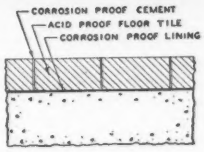

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THE ATLAS MINERAL PRODUCTS COMPANY
MERTZTOWN, PENNA. HOUSTON, TEXAS

Clippings on Corrosion

(Continued from Page 13)

with lead-cadmium alloy by adding aluminum which reduces dross adherence to the copper surface, thereby improving appearance and corrosion resistance.

•

ACID DESTROYS CONCRETE PIPES IN EIRE SCHEME

(From Bonham, Texas, Favorite, Oct. 11, 1950)

Dublin—Results of the first year of a 10-year, $120,000,000 agricultural drainage program initiated by Eire have largely been negativated because acid in the drain waters destroyed home-produced concrete pipe laid in the soil to remove excess waters. The drains' collapse was revealed by subsidence of the ditch fills. The project will proceed at a rate at which clay pipe can be imported from Britain and Holland.

•

TWO PAPERS ON CORROSION GIVEN AT ELECTROCHEMICAL SOCIETY'S MEETING

(From Chemical & Engineering News, Oct. 30, 1950)

Buffalo—Speaking at the ninety-eighth meeting of the Electrochemical Society here W. D. Robertson presented data to prove that molybdates and tungstates are comparable to chromates as corrosion inhibitors. Robertson said his data required that certain previous explanations of the mechanism of inhibition be modified.

Two theoretical techniques interesting to corrosion chemists were presented by Carl Wagner of MIT, a calculation by which the maximum volume over which cathodic protection can be assured under a given set of conditions; and by Paul Delahay of Louisiana State University, in which a potential pH diagram is constructed from thermodynamic data.

•

COLUMBIUM STAINLESS IS PREEMPTED FOR DEFENSE

(From Hutchinson, Kans. News-Herald, Oct. 21, 1950)

Washington—The whole production of columbium stainless steel has been preempted for defense purposes.

•

WATER CLEANER DEVELOPED FOR AUTO RADIATORS

(From Automotive Indus., Phila., Pa., Nov. 1, 1950)

Fram Corp. of Providence, R. I. has developed a radiator water cleaner for cars and trucks which strains a controlled amount of water from the cooling system and adds softening and inhibiting chemicals.

•

IMPROVED MOTOR OIL IS DEVELOPED BY S. O. CAL.

(From Dallas, Texas, Wall St. Journal, Nov. 2, 1950)

Doubled protection against corrosion is claimed for a new motor oil developed by Standard Oil Co. of California.

•

CORROSION ENGINEERS' MEET AT ORANGE, TEXAS

(From Beaumont, Tex. Journal, Oct. 26, 1950)

A meeting of the Sabine-Neches Section of the National Association of Corrosion Engineers will be held at 7:30 p.m. Thursday at Sunset Grove Country Club at Orange.

CORROSION RESISTANT NEW STEEL CAN BE MADE IN OPEN HEARTH

(From New York Times, Nov. 6, 1950)

Chicago, Ill.—The Carnegie-Illinois Steel Corp., has announced perfection of a new steel, designed for mass production from open hearth furnaces with almost double the strength of high-strength, low-alloy steels. It may be welded with standard electrodes, yet possesses almost triple the strength of ordinary welding-grade steels. It is designed to provide at least two or three times the resistance to atmospheric corrosion offered by plain carbon steels.

Research undertaken four years ago was directed toward conservation of critical alloying materials. The material uses small quantities of a comparatively large number of alloying elements that are available readily.

It has been given the designation "T 1" and is described as providing good resistance to corrosion and having the quality of remaining tough at temperatures below zero.

•

X-RAY TESTS ARMY CANS FOR CORROSION, DEFECTS

(From Great Bend Kans. Tribune, Oct. 30, 1950)

Washington—The army is using x-ray inspection of goods canned for the service which takes pictures at high speeds to disclose corrosion, deterioration or other defects in the canned foods. Savings of up to $30,000 a month over present hand inspection methods is anticipated.

•

SHIP BOTTOM CORROSION TITLE OF NAVAL PAPER

(From New York Times, Nov. 6, 1950)

Paul Field presented a paper "Some Aspects of Ship Bottom Corrosion" at the Friday, November 3, session during the 57th annual meeting of the Society of Naval Architects and Marine Engineers.

•

WESTINGHOUSE DEVELOPS 3-COAT PAINT SYSTEM

(From Hutchinson, Kans., News-Herald, Nov. 2, 1950)

Sharon, Pa.—Westinghouse Transformer Division has developed a new 3-coat paint system for transformers exposed to the weather. The principal feature of the system is a middle coat containing mica flakes. The mica is claimed to be effeective in limiting moisture and oxygen penetration and increasing the heat resistance of the middle coating as much as 10 times at high temperatures, according to J. G. Ford, engineer. The third coat is for appearance and to block ultraviolet rays.

•

POWDER METALLURGY OF BERYLLIUM EXPLAINED

(From Hutchinson, Kans. News-Herald, Oct. 31, 1950)

Chicago—Powdered beryllium compacted at room temperature then sintered in vacuo or in an argon atmosphere produces a product which has characteristics useful in nuclear reactors in atomic energy work, Dr. H. H. Hausner and N. P. Pinto, both of Sylvania Electric Products, Inc., Bayside, L. I., N. Y. told the American Society for Metals here.

Vacuum sintered beryllium has measurable ductility, reduction by cold-rolling of up to 9 percent being possible. Annealed cold-rolled beryllium has improved characteristics. Argon-sintered beryllium is brittle.

•

PURE VANADIUM ATTRACTS ATTENTION AT DISPLAY

(From American Metal Market, Oct. 26, 1950)

Chicago—Pure vanadium produced by the Electrometallurgical Division of Union Carbide and Carbon Corp. was displayed at the Metal Show here. A. B. Kinzel, vice-president of Union Carbide and Carbon said recently development of the pure metal has been stimulated by the search for metals having certain reactions to bombardment with neutrons in connection with atomic problems.

Massive vanadium in chip form for remelting into ingots is about $30 a pound. Semi-finished and hot-rolled and machined plates 10 x 3 x ⅜ inch are quoted nominally at $60 a pound.

•

ALL-PLASTIC TUBING IS USED ON SALT WATER WELL

(From Corpus Christi, Texas. Times, Oct. 15, 1950)

The first string of all-plastic tubing has been run into a salt water disposal well on a Kansas oil lease. The pipe also is being tried on gravity and low-pressure pipe lines carrying corrosive crude, raw gas and waters.

•

WATER PURIFIED TO STOP CORROSION, SLUDGE

(From Oklahoma City, Okla. Oklahoman, Oct. 8, 1950)

Water used to replenish the Mustang plant system is purified to prevent corrosion and sludge deposits. The water goes to a treatment house where precipitators remove most of the impurities and then is acid treated in an automatic system which burns sulfur to produce acid as needed.

Another system of filters and softeners treats water taken into the boiler system.

•

ZIRCONIUM OUTPUT IS INCREASED IN OREGON

(From New York Times, Oct. 29, 1950)

Chicago—Northwest Electro Development Laboratory of the Bureau of Mines at Albany, Ore., has pushed production of zirconium to 1000 to 1200 pounds weekly. Virtually all the output goes to the Atomic Energy Commission.

Widespread industrial uses loom for the metal because of its corrosion-resisant qualities.

•

SEWER SYSTEM "CORRODED" BY PACKING PLANT GREASE

(From Fremont, Neb. Guide & Tribune, Sept. 30, 1950)

City councilmen considering sewage disposal problems estimated a disposal system for the city's sewage would cost $400,000 without refuse from the Hormel plant and $750,000 with refuse from the plant. Councilman Irving Peterson said "The city's sanitary sewer system is 'corroded' with grease from the plant."

•

GLASS FABRIC BOAT HULLS MAY BE MASS PRODUCED

(From Owensboro, Ky. Inquirer, Oct. 25, 1950)

New Bedford, Mass.—Production of one 24-foot pleasure cruiser a day is forecast by mass-production methods utilizing a combination of Laminac, a polyester resin and Fiberglas reinforcing mat. The hulls are formed in molds, with moulded-in plastic gasoline tank, water tank, icebox and sink.

NEW PRODUCTS – Materials – Service – Literature

Colclad, stainless clad steels are manufactured by Colville's Limited, Glasgow, Scotland. Backing steel normally is of British Boiler Quality, but may be provided with other backing to suit other specifications. Cladding metals comprise 18/8 Ti, 18/8 Nb, 18/10/2 Nb and 14 percent Cr. A 28-page brochure lists specifications of the clad metal, illustrates results of various durability tests and depicts several uses for the composite, including vessels for chemical process industries, cracking towers, and other types of equipment. The company, among other things also produces Corten corrosion resisting high strength steel. Executive offices are located at 195 West George St., Glasgow C2, Scotland.

•

A Catalog listing control, testing and telemetering instruments has been issued by W. J. Kantenberger Co., 722 S. Hampton Road, Dallas 11, Texas.

•

Glidden Company protective linings are described in a 12-page booklet issued by The Glidden Co., 11001 Madison Ave., Cleveland 2, Ohio. Linings for drums, and pails for packaging animal and vegetable oils, products of oil refiners, vegetable salts, acids, alkalies and other corrosives are detailed.

•

Cooper Alloy Foundry Co., Hillside, N. J., has issued a 4-page Materials Selection Chart in which is tabulated a long list of corrosives in various states and at various temperatures, together with recommendations respecting each of five metals and alloys for use with each corrosive. The list includes 350 corrosive conditions.

•

Cadweld splice welders for joining cable, quick connectors and terminal lugs provide a 100 percent efficient connection, Erico Products, Inc., 2070 East 61st Place, Cleveland 3, Ohio, claims. Ends to be joined are positioned in a graphite crucible, powdered copper oxide and aluminum are dumped in and ignited by means of a spark. The resulting bond is a fusion weld of 98 percent copper with a 50 percent greater cross section than the cable. The joint, which can be made in one minute, is not subject to gradual loosening by oxidation, manufacturers say.

•

Terne Metal roofing now is being manufactured in volume by Follansbee Steel Corp., Pittsburgh, Pa. Seamless 50-foot rolls of the material are offered. The base metal is copper-bearing steel, heat treated to provide a balance between malleability and toughness, dip-coated with ternemetal, an alloy of about 80 percent lead and 20 percent tin. The resulting plate has high corrosion resistance and is readily painted any color, manufacturers say.

•

Munray Products, Inc., has issued a new folder detailing characteristics and uses of Cyclon corrosion-resistant materials of construction.

Ebasco Services, New York City will manage and direct the development and operation of a power system for Greece ultimately expected to cost $200,000,000. The Economic Cooperation Administration is assisting in financing the project.

•

Industrial Chemical Products, S. A. (Pty.) Ltd., Johannesburg, South Africa, has completed a new lant at Lilianton, Boksburg, for production of industrial, metallurgical and agricultural chemicals and chemical specialties.

•

Dy-Chek, a means of non-destructive surface testing involving the application of a special material which is applied and developed to reveal defects is explained in a series of bulletins numbers 101 through 106 bearing on various aspects of the method. The process was developed by Dy-Chek Company, 1515 East Broadway, Hawthorne, Cal.

•

Phenoline, a resin allied to those in the phenol formaldehyde thermosetting group, sets at 60 degrees or higher into a hard, glasslike surface, highly resistant to wear and corrosion and resistant at all concentrations of organic and inorganic acids except nitric and chromic, according to the Carboline Co., 7603 Forsyth Blvd., St. Louis 5, Mo. Product Data Sheet C-51 covers characteristics of the material.

•

Carpenter Stainless No. 8 (AISI type) will contain sulfur instead of selenium as a free-machining agent in the future because of a sharp advance in the price of the latter additive. Selenium-containing steel will be supplied on order at a premium price, however, as long as the additive is available.

•

"Electrolytic Deposition of Asphalt as a Means of Pipe Protection," a reprint of a paper presented at a meeting of American Water Works Association sections at Washington, D. C., by George H. Dann, superintendent, Philadelphia Suburban Water Company, Bryn Mawr, Pa., is available from Pittsburgh Pipe Cleaner Co., 133 Dahlem St., Pittsburgh 6, Pa. The paper describes the Pittsburgh-Eric Process for reconditioning pipe. The firm also has an improved cement lining machine for pipe over 24 inches OD. Luconal, a rapid air-drying solvent solution of Lucoflex, a nonflammable, unplasticized polyvinyl chloride plastic, also is a product of this firm.

•

Color Chip cards consisting of actual paint samples of its Totrust Enamels are available on request from the Wilbur & Williams Company, Greenleaf and Leon St., Boston 15, Mass.

•

R-108 is the designation given a new series of baking-type coatings developed by General Electric's Chemical Department. The series combines chemical resistance with flexibility and heat resistance. Based on phenol derivitives developed by the company they may be pigmented and may be applied with standard equipment and conventional techniques. They are designed to combine the outstanding properties of both vinyl and conventional phenol coatings. Being produced on a semi-commercial basis, the material is available in drum and tank car lots. Its anticipated uses include coatings for drums, food containers, tank cars chemical tanks, process equipment and appliances.

•

Hysol 6000, a product of Houghton Laboratories, Inc., Olean, N. Y., is an odorless, tasteless and non-toxic thermosetting plastic with outstanding resistance to acids and alkalies, according to the manufacturers. The material can be sawed, turned, drilled, routed and shaped. The company supplies a folder with specimens and schedule of specifications, electrical and chemical resistance properties.

•

"Karbate" brand impervious graphite pumps have been reduced in price to the point that they now may fill the demand for standard all-purpose corrosion resistant equipment. Karbate resists the action of acids, alkalis and salt solutions and organic compounds, making possible to use pumps without regard to specific service. The pumps use Teflon gasket material, have an imperious graphite case and impeller and rotary seal that eliminates the stuffing box. They are manufactured by National Carbon Division, Union Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y.

•

Ucilon protective coatings based on vinyl resins, phenolic resins, fish oils, chlorinated rubber and water emulsions are described in a new bulletin issued by United Chromium, Inc., 100 East 42nd St., New York 17, N. Y.

•

National Carbon Division of Union Carbide & Carbon Corp. will increase its productive capacity for carbon and graphite anodes by many million pounds annually by additions to its Columbia, Tenn., Clarksburg, West Va., and Niagara Falls, N. Y., plants.

•

"Lead in Modern Plumbing," a publication of the Lead Industries Association, 420 Lexington Ave., New York 17, N. Y., explains and illustrates the uses of lead piping, joints and plumbing elements in various kinds of construction and for both sanitary and fuel installations. Economics, specifications, tables of standards and blue prints of ideal installations most frequently seen are included.

•

Anti-rust properties of Gulf Oil Corporation's Lasupar cutting oils are claimed improved as a result of recent improvements.

•

Adams Modern Filtration Equipment, Bulletin No. 691 is available on request from R. P. Adams Co., Inc., 220 East Park Ave., Buffalo 17, N. Y. The 20-page, 8½x11-inch brochure explains and illustrates equipment produced by the company for producing clean water for drinking and for industrial uses.

(Continued on Page 16)

New Products

(Continued from Page 15)

Varniton plastic paint, plastic strip coating and No-Slip Concrete Paint are detailed in a 4-page data sheet available from The Varniton Co., 416 North Varney St., Burbank, Cal. Varniton plastic paint is made for dipping or brushing, can be applied without a primer and is resistant to fumes, light and heat. The product is recommended for use in laboratories to protect wood, metal and ceramic surfaces. The data sheet includes a table listing the resistance of the several types of paint against 85 destructive chemicals. Varniton plastic strip coating may be applied to surfaces subjected to organic solvents, oils and greases. The water soluble clear paint dries to a glossy finish. The dried coating may be stripped from the surface if desired. No-Slip Concrete Paint is specially prepared to prevent slipping on wet concrete surfaces. It is resistant to strong acids, alkalis and salts and is recommended for laboratory and industrial concrete floor areas in front of sinks and other working places. Varniton plastic crack filler may be used to repair cracks and holes in wood, cement asbestos board, brick, soapstone, concrete and ceramic tile. When dry it resists water, acids, alkalis and salt solutions, but not organic solvents.

•

Haertel industrial dehumidifiers, powered with a 12-HP sealed condensing unit, have maximum 24-hour water removal capacity of 50 pounds. One gallon of water from the air in a closed space in four to five hours under average temperature and humidity conditions can be removed by these units, the company claims. Manufacturers are Walter Haertel Co., 2840 Fourth Ave., South, Minneapolis, Minn.

•

Zinkrich Cold Galvanizing Compound, a product of Chase Chemical Corp., 40 West 29th St., New York 1, N. Y., when applied by spray, brush or dip to a metal surface forms a metallic bond with the metal, the company claims. The resultant coating is 96 parts by weight pure zinc and has the advantage over coatings containing zinc or aluminum dust in suspension in that it is continuous electrically with the coated surface, the company claims.

•

Allied Services, Inc., Spring and Bullit Streets, Charleston, W. Va., has been named sales and service representative for southern West Virginia by the Dampney Co. of America, Boston, Mass.

•

Cast Iron pipe now is being produced at the new foundry of Lone Star Steel at Daingerfield, Texas. The new plant and the Reilly Tar & Chemical Corp. plant were dedicated December 4. The Reilly plant will produce coal tar coatings for Lone Star.

•

Glasfab now is offered as part of a "package" subfloor for use in construction of corrosion resistant floors by Special Chemicals Department, Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia 7, Pa.

•

Metacon 520 is an improved rust remover of the phosphoric acid type containing additives to give it special desirable properties. It is recommended for use as an alternate to or substitute for mechanical cleaning. Manufacturers, Croda, Ltd., Croda House, Snaith, Goole, Yorkshire, England, claim a surface derusted with Metacon 520 is simultaneously rendered anti-corrosive and far more resistant to corrosion than the original rust-free surface. The matt finish left on ferrous metal surfaces is an advantage for paint bond. Painting may follow as soon as the remover has dried. Tests reported by the manufacturers in industrial chemical laboratory atmospheric conditions indicate Metacon-treated mild steel panels remained free from corrosion for at least eight weeks while suspended from the laboratory roof where they were exposed to corrosive vapors from below. The compound, supplied as a liquid, must be applied to a degreased surface. It reacts strongly on aluminum and attacks bare skin.

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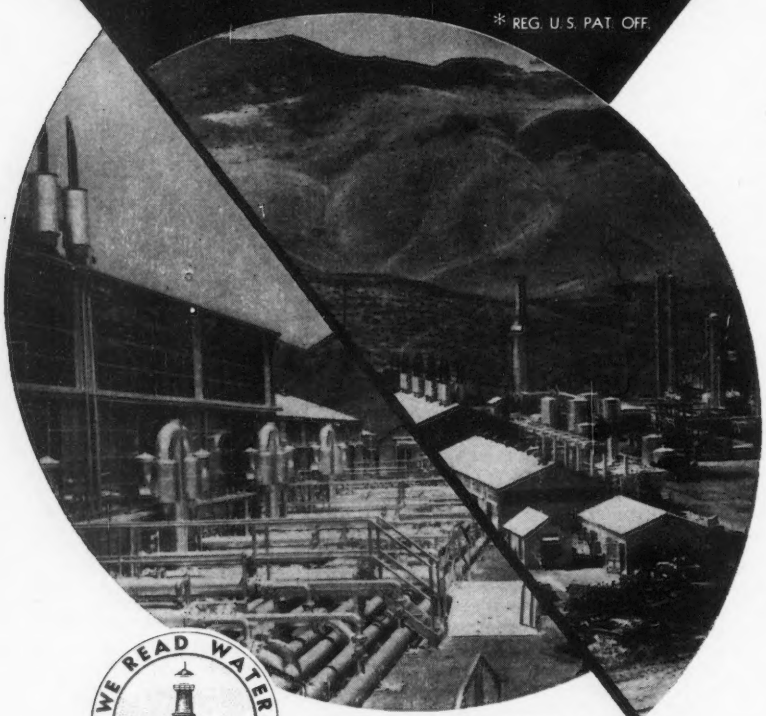

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PERSONALS

R. V. Hanrahan has retired as president of Humble Pipe Line Company and has been succeeded by **O. Q. Lomax. A. E. Pecore** has been elected vice president.

•

Philip Getter, erecting engineer for Koppers Co., Inc. has been awarded the Bernardo O'Higgins Order of Merit in the rank of Comendador by the order of President Gabriel Gonzales Videlia, of Chile.

•

Chester F. Conner, industrial products salesmanager for the B. F. Goodrich Company has been retired and Paul W. Van Orden has been named industrial products merchandise manager.

•

Clifford Off, Jr., and **Harry E. Rapp** have been appointed to the board of directors of Insul-Mastic Corp., Pittsburgh, Pa. Mr. Rapp is technical director of the company. Mr. Off is sales manager.

•

Kenneth L. Sayre, Gordon W. Andersen and **Edward G. Appel** have been named to the staff of the Bjorksten Research Laboratories, Inc., Madison, Wis.

•

E. W. "Red" Lawlor has been transferred to the Tulsa, Oklahoma, office of Pittsburgh Coke & Chemical Co.'s protective coatings division.

•

D. B. Bishop has been named manager of the Pittsburgh office of Dearborn Chemical Co., replacing **J. A. Crenner,** who retired September 30 after 37 years of service.

•

Frederick E. Herstein has been appointed sales representative in northern New Jersey and parts of New York state by Glascote Products, Inc. He has been active in the corrosion resistant chemical equipment field since his graduation from Polytechnical Institute of Brooklyn in 1936.

•

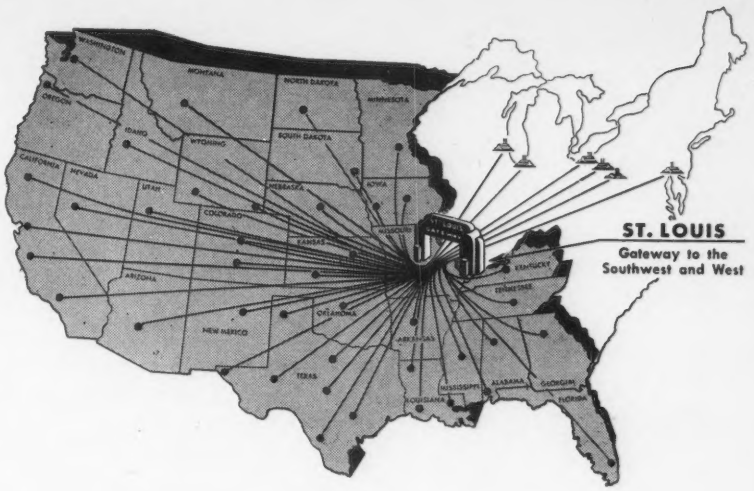
Donald O. Notman has been named general manager and **Charles B. McCoy** assistant general manager of the electrochemicals department of E. I. du Pont de Nemours & Co. **Samuel G. Baker,** formerly general manager of the department, was named to succeed **James S. Denham,** general manager of the photo products department, upon the latter's retirement Dec. 1.

•

Chet Borlet has joined the sales and service staff of United Chromium, Inc., and will operate from the Los Angeles regional office of the company.

•

Albert M. Fiala has been named manager of government sales in the industrial products department of B. F. Goodrich Co.



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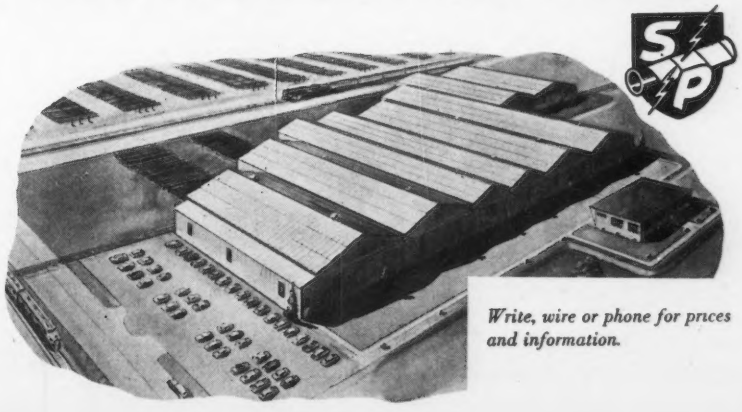

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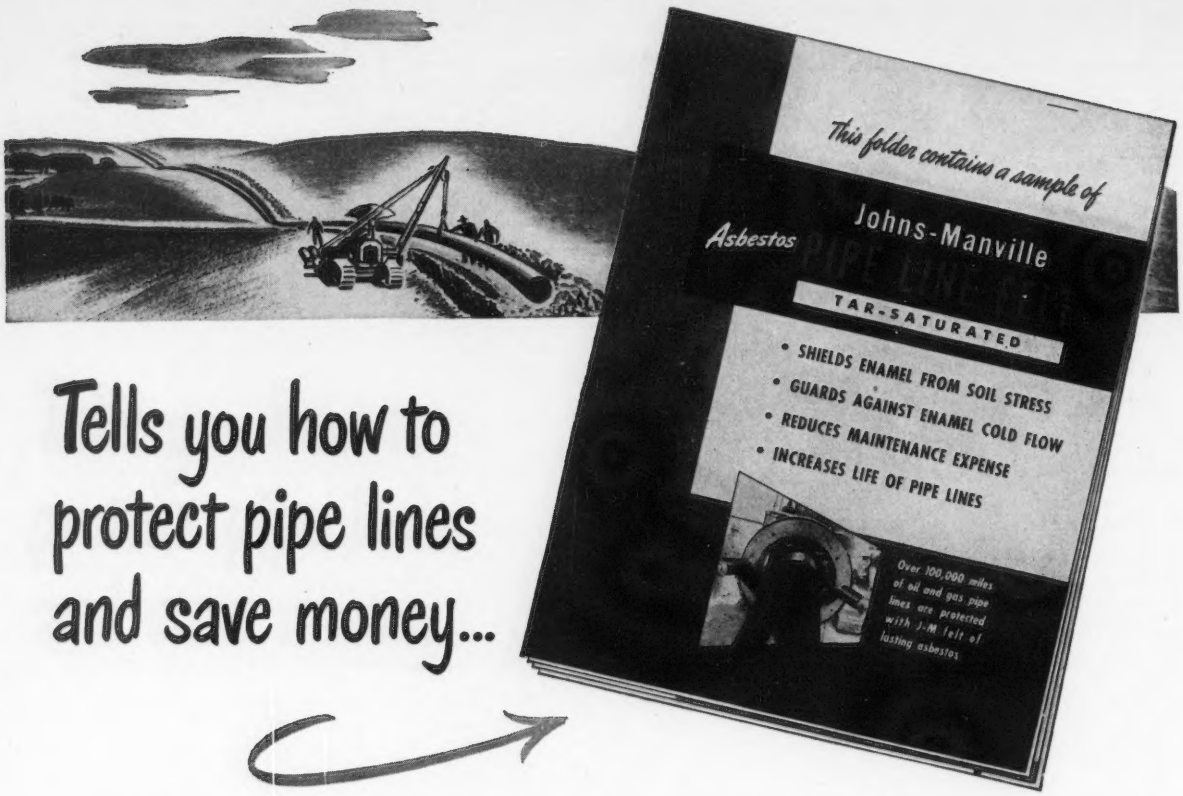
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Corrosion Abstracts

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*** PAGINATION OF CORROSION ABSTRACTS**

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, effective with this issue the "Index to Corrosion Abstracts" will be keyed to the number found in the lower outer corner of each page followed by the letter "a."

GENERAL

• Books

1.6, 1.8

International Conference on the Physics of Metals (Amsterdam 12-17 July 1948). Martinus Nijhoff. Med. 8vo. Pp. (ix) + 271, illustrated. (1949) The Hague:

An International Conference on the Physics of Metals was held in Amsterdam from 12 to 17 July 1948. The papers presented were subsequently published in *"Physica"* [1949, 15, (½)], and abstracts of them appear in this issue of *"Metallurgical Abstracts."* The present work is an exact reprint of this issue of *"Physica,"* except for the addition of a brief explanatory preface and the omission of the last of the 39 papers originally published.

The conscientious reviewer of a book has to take into account many factors, which include the author's point of view, his method of treatment, the factual accuracy, the material selected, the literary style, and so on. If the work under review contains, as does this one, 38 variants of each factor, in either English or French, the reviewer is reduced to a mere indication of the value and scope of the book. An indication of value is easily dealt with; the book is invaluable, both to those who attended the conference and wish for a permanent record of the words they heard, and to those who did not go but wish to find out what went on. The latter class ought to be a large one, because, though physical, the papers contain much material of importance to the physical metallurgist.

Some of the papers take the form of critical reviews of progress made during the last ten years, or of assessments of the present position with regard to some special branch of the theory of the solid state. Among these may be mentioned Kronig's paper on the electronic structure of metals, Gorter's paper on supraconductivity, and Van Vleck's assessment of the present status of the theory of ferromagnetism. Most of the papers, however, describe relatively recent work on problems of the solid state, from Pauling's resonating valence-bond theory of metals to the internal friction of ferromagnetics. Many of the contributions have obviously been abridged or condensed, with the result that they are either easily understood but superficial, or detailed but in parts obscure. They suffice, however, to present the general picture, and most deficiencies in detail are made good by the references given.

It will be realized what a wealth of information is contained in these contributions from English, French, American, Dutch, Belgian, Swiss, Danish, and Czechoslovakian sources. Many familiar names appear: Sir Lawrence Bragg writes on further developments in connection with his bubble-raft model of a crystal, Zener on relaxation phenomena, Mott on dislocation theory, Hume-Rothery on the sizes of metal atoms, Borelius on the thermodynamical theory of ordering and precipitation, and Burgers on recrystallization. Lacombe's experiments on sub-boundary structures in aluminum and the phenomena of polygonization find a place, while the account of Guinier's recent work is of great interest. Some new theoretical treatments are presented, in connection with thermal agitation and the processes depending on it (Crussard), and coercivity in ferromagnetics (Louis Neel). The last twelve papers deal specifically with the various aspects of ferromagnetism, special attention being paid to ferromagnetic reso-

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.
ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.
AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.
BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.
BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.
BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.
CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.
CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.
EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.
GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.
INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.
IP—Institute of Petroleum. 26 Portland Place, London W#1, England.
MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.
ME—Marine Engineering, The Institute of Marine Engineers. 85/88 The Minories, London E. C. 3, England.
MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.
NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.
NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.
PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.
RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.
RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.
RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.
TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.
TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.
UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.
ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

nance and the domain structure of ferromagnetics.

The whole book is an authoritative account of recent work in the field of metal physics, and, though the expert may wish for more detail in several of the papers, it is of great potential value to the physical metallurgist who takes an interest in the theoretical side of his subject.—MA.

• Fundamentals

1.8, 2.1

Reactions of Ions in Aqueous Solutions with Glass and Metal Surfaces. (Studies with Radioactive Tracers.) James W. Hensley, Arthur O. Long, and Jonh E. Willard, *Ind. and Eng. Chem.*, **41**, No. 7, 1415-1421 (1949).

The exchange and adsorption reactions of glass and metal surfaces with ions in aqueous solutions were studied by a method consisting of immersing small flat samples in a solution of the radioactively tagged ion or molecule, removing, rinsing, and drying the samples, and determining the intensity of the radioactivity on each with a Geiger-Muller counter. Tests were made on the sorption of sodium ions on fused silica, steel, aluminum, silver, and platinum and of sorption of caesium and silver ions on soft glass. The work described is mainly exploratory, but it is considered that such studies may contribute to a fundamental understanding of surface phenomena and may be of practical importance in fields such as detergent action, electroplating, mirror formation, glass electrode operation, and the catalytic effects of surfaces. One of many interesting results found was that the sodium ion is picked up by aluminum, iron, silver, and platinum specimens immersed in sodium carbonate solutions. C+, *J. ACS*, **70**, No. 9, 3146-3147 (1948).

CORROSION TYPES & INFLUENCING FACTORS

• Factors Electrochemical

Overvoltage of Hydrogen on Porous Iron. (In Russian.) L. L. Kuzmin and V. S. Poroikova. *Zhurnal Prikladnoi Khimii* (Journal of Applied Chem.), **22**, 572-577 (1949) June.

The reduction of hydrogen overvoltage on electrodes with built-up surfaces of porous iron obtained by powder metallurgy was investigated. Influence of conditions of electrode production on potential was established. Shows that, at high current densities, hydrogen overvoltage is approximately 0.3 volt less than on smooth iron. Experimental data are tabulated.—BLR.

3.6, 1.8

Cathodic Overvoltage in the System Ferric Iron-Ferrous Iron. (In French.) Eugene Lewartowicz. *Comptes Rendus* (France), **229**, 362-365 (1949) Aug. 1.

In order to apply the modern theory of overvoltage to oxidation - reduction systems the relationship between the voltage and current of a polished Pt cathode in an acid solution of ferric alum was investigated. Overvoltage up to 100 millivolts were studied. Results are charted.—BLR.

• Factors Metallurgical

3.7, 6.2

Experiences With Corrosion of Ferrous Metals Caused by Surface Irregularities. (In French.) R. Binaghi. *Metaux & Corrosion*, **24**, 216-222 (1949) Sept.

Presents results of experimental investigation of 10 alloy-steel and 14 tool-steel specimens of varied composition. Effects of composition, heat treatment, passivation, and discontinuity of conditions are evaluated. Results are tabulated and illustrated by photographs of test specimens. 16 ref.—BLR.

3.7, 6.2

Silver Alloy Brazing Stainless Steel. C. H. Chatfield and A. W. Swift. *Welding J.*, **28**, 1142-1146 (1949) Dec.

Discusses and attemps to clarify some of the specific problems encountered in silver brazing of the various stainless-steel alloys. These include cleaning and fluxing, carbide precipitation, types of stress cracking, corrosion resistance, and tensile strengths of the joints.—BLR.

3.7, 6.3

Corrosion. M. G. Fontana. *Ind. & Eng. Chem.*, **42**, No. 2, 73A-74A (1950) Feb.

Recent developments in copper and copper-base alloys for corrosion applications are described. Addition of about 0.5 iron to copper-nickel results in marked improvement in resistance to erosion-corrosion or impingement type attack. Addition of 0.5 tellurium to copper gives improved machinability. Tellurium-copper is used where corrosion resistance, extensive machining, high conductivity, copper, color, or combinations of these properties are required.—INCO.

3.7, 2.3

Method of Study of Visible Irregularities on the Surfaces of Metals Resulting from Plastic Deformation. (In French.) J. Herenguel and M. Scheidecker. *Rev. de Metallurgie*, **46**, 537-543 (1949) Aug.

Describes above method, which consists of study of corrosion patterns and slip lines. Indicates that mascroscopic irregularities are related to the microstructure resulting from a series of recrystallizations. Macrographs, micrographs, and diagrams.—BLR.

3.7, 3.5, 2.3

Stress-Corrosion Cracking in Welded Steel Structures. C. E. Pearson and R. N. Parkins. *Welding Res.*, **3**, (bound with *Transactions of the Institute of Welding*, **12**), 95r-106r (1949) Dec.

Gives details of work undertaken to investigate a failure in a welded mild-steel gas main carrying saturated crude coke-oven gas at 35-40° C. Cracking in coke-oven gas and in a boiling solution of 60% Ca $(NO_3)_2$ + 3% NH_4NO_3 was found to be sufficiently related so that the latter could be used as a test method. Effects of various factors such as cold working prior to welding, low-temperature and peening treatments after welding, and anodic and cathodic treatments were investigated. Conclusions are summarized. Tables and macrographs.—BLR.

CORROSIVE ENVIRONMENTS

• Atmosphere

4.2, 2.3, 6.2, 6.3

Influence of Relative Humidity and Surface Conditions on the Corrosion of Low-Carbon Steel and of Zinc. F. Ogburn, E. R. Weaver, and W. Blum. *Metaux et Corrosion*, **25**, No. 283, 77-84 (1949).

Specimens of low-C steel and of Zn, the surfaces of which received various pretreatments, were exposed to atmospheres of different humidities, and the corrosion occurring was estimated visually, by increase in weight, and by loss in weight after removal of the corrosion product. After immersion in sea water and drying, Zn corroded rapidly and the effect of the relative humidity of the atmosphere was marked; increasing the relative humidity from 50-70% more than trebled the rate of corrosion. Zn given a Cronak finish by dipping in a solution containing Na dichromate and sulfuric acid only corroded slowly even in atmospheres of high relative humidity.—INCO.

4.2, 5.3

Electrodeposited Coatings for Atmospheric Corrosion Protection. F. Ogburn (Nat. Bur. Standards.) *Product Eng.*, **20**, No. 12, 135-139 (1949) Dec.

Products made of steel or Zn-base die castings are effectively protected against atmospheric corrosion by electroplated coatings of Zn, Cd, Ni, Cr, Cu, and several other metals. The length and quality of protection given depend on the type of atmospheric corrosion, coating and base metal. Tables are included.—INCO.

• Chemicals Inorganic

4.3, 6.5, 5.4

Caustic Soda versus Construction Materials. Symposium on Caustic Soda vs. Construction Materials. *Chem. Eng.*, **56**, No. 12, 213-214+ (1949) Dec.; **57**, No. 1, 213-214+ (1950) Jan.

Papers included are:

Chlorimet by W. A. Luce.

Worthite by W. E. Pratt which includes a table of laboratory corrosion tests in 50% NaOH comparing Worthite with Monel, nickel and stainless 304.

Lead by K. H. Roll.

Glass Linings by S. W. McCann.

Rubber Linings by E. L. Lockman.

High-Silicon Iron by W. A. Luce.

Stainless Steel by W. G. Renshaw.

Cements by R. B. Seymour.

4.3, 5.5, 6.7

The Corrosion Forum-Fluorine versus Construction Materials Symposium on Fluorine versus Construction Materials. *Chem. Eng.*, **56**, No. 11, 201-202 (1949) Nov.

Symposium includes:

Carbon and Graphite by J. F. Revilock and N. J. Johnson, Nat. Carbon Co.

Stainless Steel by W. G. Renshaw.

Lead by K. H. Roll.

Iron and Steel by A. W. Spitz.

Worthite by W. E. Pratt.

Among the materials not recommended are chemical stoneware, tantalum, and aluminum.—INCO.

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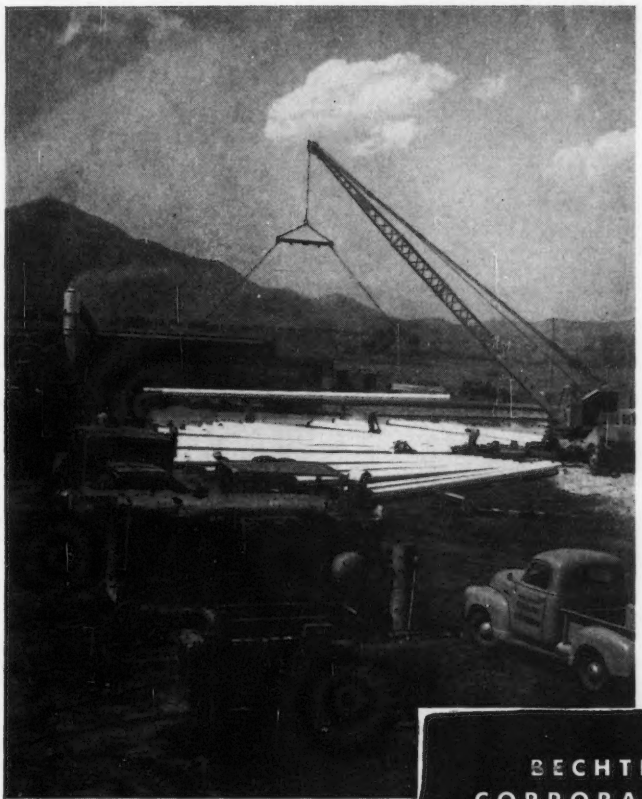

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3a

4.3, 8.8

Hydrofluoric Acid Anhydrous. Harshaw Chemical Co. Brochure, 1949, 36 pp. Published by the Company, Cleveland 6, Ohio, U.S.A.

A collection of useful data: physical and thermodynamic properties (including density/temperature and vapor pressure/temperature curves); corrosion resistance of materials of construction to HF liquid and vapor; satisfactory types of construction for valves, pumps, gauges, pipe, and meters for use with HF; handling and first aid; storage tanks; sampling and analysis; use in organic syntheses.—MA.

4.3, 8.8, 7.10, 6.3

Pickling Equipment for Severe Corrosive Conditions. C. B. Mitchell. *Iron Age,* **164,** No. 18, 92-93 (1949) Nov. 3.

Use of an unusual combination of five different alloys in the fabrication of hook and bar pickling assemblies yields maximum strength and corrosion resistance at minimum cost. Hastelloys B and C and type 347 stainless steel were used for construction of the hooks and bars were made of Hastelloy B and SAE 4340 and 1035 steels. A service life of more than 10 years is expected.—INCO.

• Chemicals Organic

4.4, 6.3

The Corrosion of Lead by Xylene Solutions of Lauric Acid and p-Quinone. C. F. Prutton and J. H. Day. *J. Phys. & Colloid Chem.,* **53,** 1101-1117 (1949). *J. of the Amer. Oil Chem. Soc.,* **27,** No. 1, 35 (1950) Jan.

Pb is rapidly corroded by oxygen-free xylene solutions of p-quinone and lauric acid, neither of which by itself attacks Pb appreciably. The reaction rate is increased by the presence of water and is unaffected by the presence of Pb laurate.—INCO.

• Soil

4.5, 3.3, 1.7

The Underground Corrosion of Ferrous Metals in the Light of Recent Research. K. R. Butlin and W. H. J. Vernon. Chem. Eng. Group (Soc. Chem. Ind.) Paper, Dec. 6, 1949.

Discusses the mechanism of soil corrosion, particularly that occurring in anaerobic conditions and associated with the activity of sulfate-reducing bacteria. Recent work on microbiological corrosion at the Chemical Research Laboratory is reviewed, and the practical aspects of the problem are discussed.—BNF.

4.5, 2.2

Soil Corrosion Studies, 1946: Ferrous Metals and Alloys RP2057. I. A. Denison and N. Romanoff. *J. Res. NBS,* **44,** No. 1, 47-76 (1950) Jan.

The results of measurements of corrosion made on a variety of wrought and cast ferrous materials after exposure to different soil conditions for periods up to 14 years are reported. Steels containing small amounts of nickel (0.52-3.32) and chromium showed increased resistance to soil corrosion, but the resulting improvement was small. Certain austenitic steels containing high percentages of chromium and nickel (11.95-22.12) were completely resistant to corrosion. In those soils in which there was a significant difference in the pitting of cast iron and wrought materials, cast iron usually pitted at somewhat higher rates. High sustained rates of corrosion occurred in poorly aerated soils high in soluble salts or in acidity. In well aerated soils low in soluble salts, corrosion virtually ceased after a relatively short time because of the formation of layers of corrosion products close to the metal surface. Charts. Photographs. — INCO.

4.5, 5.2

Potential of Corroding Iron Construction and Protective Potential Under Conditions of Cathodic Protection. I. N. Frantsevich and T. F. Frantsevich-Zabludovakaya. *Zhurnal Prikladnoi Khimii,* **22,** No. 8, 793-800 (1949). *Chem. Eng.,* **56,** No. 12, 250, 252 (1949) Dec.

The surface of underground pipes is divided into anode and cathode portions due to such factors as non-uniform construction of the pipe surface, the different nature of the soils penetrated by the pipes, effect of differential aeration, action of erratic currents, depolarizing action of biological factors. Anode portions are the points of breakdown, and the rate of breakdown is determined by the quantity of electricity passing between the anodes and cathodes in this multi-electrode system. Destruction of the metallic surface can be inhibited by a sharp reduction in internal resistance, which is attained by application of protective coatings with high dielectric properties, or by artifically equalizing the potential of anode and cathode portions which is accomplished by method of cathodic protection. Minimum negative potential supplied from an outside source which will assure a 95-99% decrease in corrosion is 0.28-0.3 v.—INCO.

4.5

Effect of Alloy Composition on the Corrosion of Ferrous Metal. Paper before Amer. Gas. Assoc's Joint Prod. & Chem. Comm. Conf., 1948. *Ind. Fin.,* 362-365 (1949) Jan.

Describes tests on ferrous and nonferrous materials exposed for prolonged periods to various types of soil. Appears to be based on the National Bureau of Standards tests of Circular 450, 1945.

4.5, 5.2, 3.6

Corrosion and Its Causes. N. P. Peifer. *AGA Monthly,* **32,** No. 2, 48-50 (1950) Feb.

Causes of corrosion in underground structures are encountered and described. Diagrams are given for pitting, corrosion caused by dissimilar soils, differential aeration of soil, mixture of different soil, cinders, dissimilar metals, dissimilarity of surface conditions and cathodic protection by Mg anode and Mg ribbon.—INCO.

• Water and Steam

4.6, 7.2, 6.3, 1.7

Domestic Copper Piping — Causes of Pitting Corrosion. *Metallurgia,* **41,** No. 245, 271-272 (1950) Mar.

The British Non-Ferrous Metals Research Association has been studying the behavior of Cu pipe in supply waters with special reference to pitting which occurs in some cold water pipes. The two pipe materials, phosphorus-deoxidized non-As Cu phosphorus-deoxidized arsenical Cu, are equally satisfactory. The pitting corrosion is usually due to the presence of carbonaceous or other films which may be produced inside the tubes by some manufacturing conditions. Pitting does not occur in the majority of Cu pipes even if carbonaceous films are present. These films are formed during manufacture by decomposition of remnants of drawing lubricant when a non-oxidizing atmosphere exists in the tube during annealing. The only type oxide film with which pitting is associated is a closely adherent shiny, reddish layer. —INCO.

4.6, 1.7

Water Softening: Report of the Water Softening Sub-Committee of the Central Advisory Water Committee. Ministry of Health. Brochure, 75 pp (1949). H.M.S.O. 1s. 6d., B.N.F. Serial 33,202.

Report on the desirability of softening of public water supplies in hard water areas, including information concerning the relative corrosive action of hard and softened waters on mains, service pipes, and Al cooking utensils; fuel economy and scale formation, etc.—BNF.

4.6, 3.3

Aerobic Microbiological Corrosion of Water Pipes. I and II. (In English.) Erik Olsen and Waclaw Szybalski. *Acta Chemica Scandinavica,* **3,** No. 9, 1094-1116 (1949).

Part I describes the above type of corrosion and reviews the literature on it. Proposes theory that iron bacteria play a prominent part in the phenomenon. Part II describes experiments made to test the theory. Results are illustrated and charted; equipment is diagrammed. 33 ref.—BLR.

4.6, 8.2, 3.3

Project Study for the Mitigation of Marine Fouling. I. A. Patten. *ASME.* Paper No. 49-S-20 (Preprint), 10 pp, (1949) May.

Describes attempts to control marine fouling in power station condensers, pumps, intakes, etc., by chlorination. Corrosion occurring was initially ascribed to chlorination, but was eventually found to be due to excessive aeration of the cooling waters and to stray current electrolysis. Chlorination is shown to lead to considerable annual saving.—BLR.

4.6, 1.7

Tenth Annual Water Conference. Engineer's Soc. of Western Penn., Symposium, Pittsburgh, Oct. 17-19, 1949. *Combustion,* **21,** No. 5, 42-47 (1949) Nov.

Symposium includes:

Water Problems in the Starting of the Mitchell Power Plant of the West Penn. Power Company by W. L. Thompson.

The Problem of Generating Pure Steam at High Pressures by M. Frisch and R. A. Lorezini, Foster Wheeler Corp.

Deaerating Feedwater Heater Problems by E. B. Kuhn, Elliot Co.

Deaerating Heaters—Spray Type versus Tray Type by A. L. Jones, Worthington Pump.

Demineralization Operations at the Dow Chemical Company by L. Wirth, Jr.

Operations of the Ion Exchange Water Treating Plant at Texas City by A. R. Pettyjohn, Carbide Chemicals Corp.

Operating Experience with Resin Zeo-

lites on the Hydrogen Cycle by V. J. Calise, Graver Water Conditioning Co.

New Polar Film Treatment for the Control of Return Line Corrosion by H. L. Lewis and J. K. Brown, W. H. and L. D. Betz Co.

New treatment is octadecylamine and is called Permacol. Its action involves deposit of a non-wettable film on the inside surfaces of pipe and fittings. It deposits on corroded metal surfaces as well; it is not toxic in concentrations 100 times as great as its normal dosage of 30 ppm and does not affect the chemical characteristics of the water. Permacol provides a desirable film that offers complete protection against attack by CO_2, small concentrations of O_2, and other corrosive agents.—INCO.

4.6, 6.5, 7.4

Sea Water for Cooling. W. Z. Friend. Paper before AIChE, Symposium on Water Problems of the Process Industries, New York, Nov. 17, 1949, 35 pp.

Deals with effects of sea water upon metals and alloys including steel and iron, stainless steel, copper and copper alloys, and nickel-copper alloys under the conditions in which they are likely to be used in cooling and heat exchange systems where sea water is used as a cooling medium. Higher velocities and brackish or contaminated water in the cooling system is covered in detail. Fouling and polluted sea water are also discussed. Graphs and many tables are included.—INCO.

PREVENTIVE MEASURES

• General

5.1

Rust Prevention of Equipment in Storage and Use. *Lubrication,* **34,** 109-120 (1948) Oct.—BL.

• Cathodic Protection

5.2

Graphite Anodes for Cathodic Protection. W. W. Palmquist. *Petro. Eng.,* **22,** D-22, D-24 (1950) Jan.

Describes use of the above, including practical calculations.—BLR.

5.2, 8.9, 4.6

Cathodic Protection of Marine Tractor. O. Osborn. *Corrosion,* **5,** No. **12,** 416 (1949) Dec.

An experiment using magnesium anodes as a supplementary method of protecting the hull of a steel vessel operating in sea water has been successfully conducted on a Chrysler Marine Tractor (Sea Mule) working in the Freeport harbor, Texas.—ALL.

5.2

I.—Management Information on Cathodic Protection of Buried Metallic Structures Against Corrosion. II.—Cathodic Protection Notification Procedures. IV.—Joint Cathodic Protection Systems. Correlating Committee on Cathodic Protection. *Corrosion,* **4,** No. 9, 3-6 (1948). *Corrosion,* **5,** No. 9, 2-6+ (1949).

These bulletins were prepared by the Correlating Committee on Cathodic Pro-

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tection (U.S.), National Association of Corrosion Engineers (No. III has not yet been issued). Bulletin I describes how underground corrosion can be stopped by cathodic protection and suggests joint efforts by neighboring operators. Bulletin II mentions procedures by which co-operation can be fostered. Bulletin IV discusses design and installation of joint systems.—BNF.

5.2

Investigation of the Double Adsorption of Cations on Bentonite. (Original text in Russian.) A. T. Davidov and G. M. Lisovina. *Colloidal Journal* (USSR), **1949,** 308-310, Sept., Oct.

Among the mineral adsorbents, bentonite occupies the most important place as an absorbent in general, as a material for purification of oils, as a catalyzer, etc. The article presents results of experiments with Crimean bentonite which has the following chemical composition: SiO_2—51.78%; Al_2O_3—17.87%; Fe_2O_3—3.43%; MgO—4.14%; CaO—2.45%; H_2O—14.42%. Loss during calcination, 0.17%.

In order to explain the character of the physicochemical functions originating on the surface of the adsorbent, studies were made to determine the functional relation of the volume of adsorption to the volume of concentration. The degree of swelling of bentonite in water and in salt solutions was determined by desiccating the bentonite at a temperature of 50°, filtering and submerging the batches of bentonite in water. The water volume was 50 and 100 ml. After 24 hr. of submersion, the degree of swelling was equal in both test tanks. The volume of bentonite increased through swelling up to 2.5 times regardless of the volume of water. The effect of $CaCl_2$ and NaCl solutions of various concentrations on the swelling of bentonite is the same as the effect of water. The volume of bentonite increases up to 2.5 times. The equation of double adsorption, as introduced by E. N. Gapon, can be well adapted for the interchange of ions on bentonite. The magnitude of full adsorption a_m, obtained according to the Gapon equation, is less than the magnitude of absorption obtained by an analytical method and equal to 121 mg to 100 gm of absorbent with the exception of the systems calcium-bentonite + NaCl and strontium-bentonite + NaCi. According to double adsorption the bivalent cations are distributed in the following order: $Ca^{2+} > Ba^{2+} > Sr^{2+} > Mg^{2+}$.—TDD.

• Metallic Coatings

5.3

Gaseous Plating. *Metal Fin.,* **47,** No. 10, 79-80 (1949).

Briefly describes a method of obtaining metal deposition by heating the article to be plated in the presence of a metal carbonyl. Carbon monoxide acts as a carrier gas for the carbonyl and provides an inert atmosphere. Infra-red heating is used. Adhesion is satisfactory and the rate of deposition high. The method is well suited to the plating of complicated shapes, irregular surfaces, and internal areas. The carbonyls of nickel, iron, chromium, tungsten, and molybdenum may all be used for the process. Deposits may be produced on any material, metallic or non-metallic, which will withstand heating to 400° F (205° C). The high speed of deposition suggests that the method would be suitable for continuous strip plating.—MA.

5.3, 6.3

Hard-Surfacing for Increased Wear-Resistance. Gilbert P. Muir. *Tool Eng.,* **22,** No. 6, 30-31 (1949).

M. discusses the advantages of hard surfacing and the procedures used. The use of cobalt-chromium-tungsten, high chromium-iron, tungsten carbide in a steel matrix, and nickel-base alloys (with chromium, molybdenum, tungsten, and iron) is illustrated with reference to resistance to abrasion, erosion, corrosion, impact, etc.—MA.

5.3, 6.3, 7.10

Recent Developments in Heat and Corrosion Resistant Coatings for Tools. E. B. Neil. *Tool Engr.,* **24,** No. 3, 34-36 (1950) Mar.

Surfaces of dies and other tools subjected to wear and abrasion are being hard surfaced either by welding the hard materials to the surface, or by electrodeposition of the material. Newest of the hard metal coatings applicable by arc-welding procedures is a Cr-carbide powder. This is mixed with water to form a paste which adheres to flat and curved surfaces. Its use is recommended where application by means of hard surfacing electrodes is undesirable, such as thin deposits, on thin work, and for use with a.c. welders. Primary undercoatings of Ni and other metals may prove more satisfactory than direct plating of the hard metal on the steel surface of the tool. The electro-deposition of W and of Ni-Co alloys on steel, and of Cr on Al (where both low weight of the tool, wear and corrosion resistance are advantageous) are new possibilities. In chrome plating, pitting of the chrome surface can be avoided only by providing a sufficiently thick deposit of Cu, Ni or other more highly resistant metal under it. The corrosion resistant characteristics of the base metal influence the thickness of the undercoating. Another development is the plating of plastics on metal to protect the tool from wear and corrosion. Nor should the depositing of white brass, black Mo, black Ni, Pb-Sn, brass, bronze, Ag, In and other rare metals be overlooked. Each has its characteristics in resisting corrosion and giving a decorative finish. Ceramin and organic coatings are also discussed.—INCO.

5.3

Protective and Decorative Nickel Plating Without Subsequent Polishing. N. T. Kudryavtsev, O. M. Korol'kova and V. V. Fedurkin. (In Russian.) *Zhur. Priklad.* Khim., **22,** No. 6, 586-591 (1949); *C. Abs.,* **44,** 50 (1950).

Bright nickel deposits were obtained with 3-4 g/l sodium or potassium salt of 2,6- and 2,7-$C_{10}H_6(SO_3H)_2$, added to a bath of $NiSO_4$ 140-300 g/l (1-2N), H_3BO_3 30, KF or NaF 5-6, KCl or NaCl 3-15 g/l; pH 5.8-6.3. The temp. can be varied from 20° to 45° C. The limits of the cathodic c.d. are, without stirring, 0.2-1.0; with stirring, 1.5-5.0 amp/dm²; the higher c.d. corresponds to the higher temp. The bright deposits are more uniform than the usual dull deposits. Brittleness becomes noticeable only at thicknesses above 25-30μ. It is attributed either to the presence of naphthol derivatives or to anodic oxidation products of the naphthalenesulphonic acids.—MA.

5.3, 5.4, 2.3

Protective Coatings and the Fight Against Corrosion. Albert Levasseur. *Inst. Franc. Petrole* (Publ.), **1948,** 46 pp.

A resume of a course of lectures delivered to the Ecole Nationale des Moteurs a Combustion et a Explosion. The compositions, properties, methods of use, and essential features of the following types of corrosion-resisting coatings are presented as short notes: a) Paints, varnishes, lacquers, etc. b) Vitreous enamels. c) Electrodeposition and electrodeposits. Recommended solution compositions and the operation conditions for nickel, copper, chromium, cadmium, zinc, and tinplating are included. d) Metal coatings other than electrodeposits—hot-dip tin and zinc, cladding, Sherardizing, calorizing, chromizing, and metal spraying. e) Coatings formed by reaction with the component—phosphate, chemical, and anodic oxidation of aluminum and its alloys, chemical treatments for magnesium, and nitriding. f) Miscellaneous—rubber, etc. Finally, methods of testing coatings are summarized.—MA.

5.3, 1.8

Tinplate. Geo. Patchin and Ernest Brewin (B.I.O.S. Overall Rep. No. 15: Ferrous Metal Industry in Germany 1939-1945, 85-87 (1949).

The production of German tinplate steel is briefly described, together with an account of the methods of pickling and coating. Hydrochloric and sulphuric acid were both used for pickling. Four coating procedures were employed for the manufacture of tinplate and tinned strip; 1) Hot-dip tinning of normal sizes in sheet-tinning machines; 2) continuous hot-dip tinning of strip; 3) electrolytic tinning of sheets; and 4) continuous electrolytic tinning of strip. Hot-dip tinning practice for sheets was not advanced beyond well-understood British practice, while strip- and sheet-tinning units were fundamentally similar. Plating vats were worked with either alkaline or acid electrolytes; some procedures involved a preliminary treatment of the sheets in a stannate and an acid stannous sulphate bath arranged in sequence. Electro-tinplate coatings on strip or sheet averaged 10 g/m², equivalent to ~8 oz. per basic box. 2 references are given.—MA.

5.3, 1.8

Coatings (Including Cladding and Bonding): Zinc Coating. Geo. Patchin and Ernest Brewin (B.I.O.S. Overall Rep. No. 15: Ferrous Metal Industry in Germany, 1939-1945, 215-217) (1949).

A review. German hot-dip galvanizing was, if anything, somewhat inferior to British and American practice, but the galvanizing shops were often strikingly clean. 1) Hot Galvanizing of Wire and Sheet. The general procedure was: a) anodic degreasing; b) water wash; c) immersion for 15 min. in cold hydrochloric acid; d) water wash for 3 min. in slowly running water; 3) anodic sulfuric acid treatment; f) water wash; g) treatment in zinc ammonium chloride flux; h) drawing through the galvanizing kettle at normal speed; i) wiping through combs or asbestos string, or close wiped with asbestos string bound round with wire, or by the use of compression pads of cork. The kettles had a capacity of 50-100 tons of spelter to which had been added 10% of lead to

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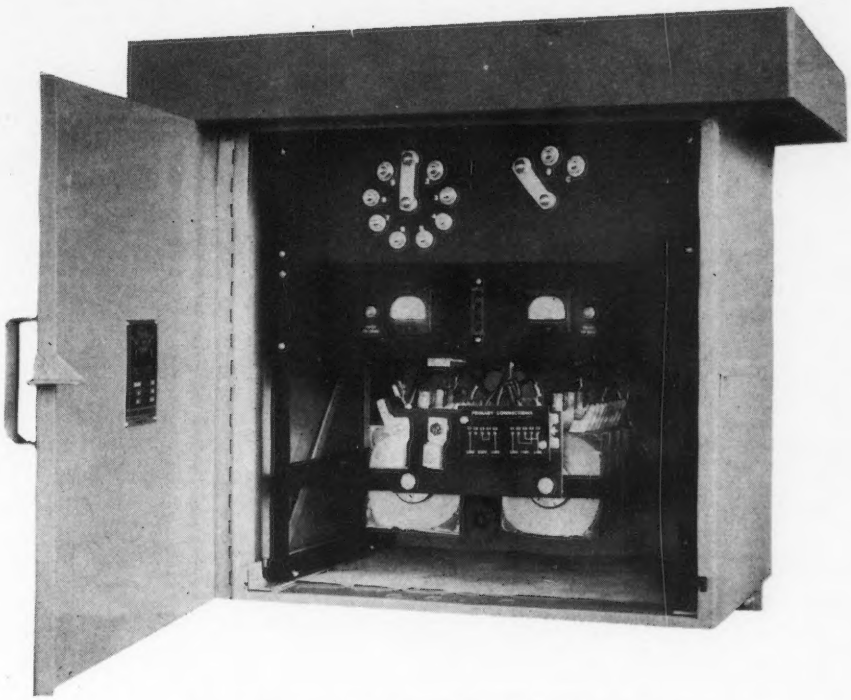

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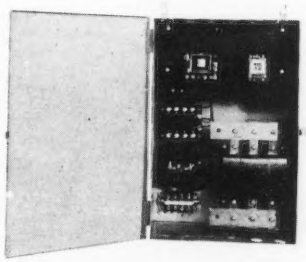

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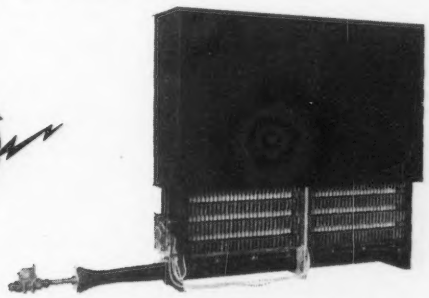

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increase the life of the kettle. The zinc coating produced was small, e.g., balloon cable had only 0.067 oz/ft²; 2) Electrogalvanizing of Cold-Rolled Strip or Wire. The following sequence was used: a) decoiling or despooling; b) electrolytic cleaning in a bath containing i) 5% caustic soda and 2% sodium cyanide, at 60° C, or ii) sodium hydroxide and carbonate at 90° C; c) water wash; d) pickling in 5% sulphuric acid; e) water wash; f) alkaline bath—cold solution of sodium carbonate; g) electrolytic cleaning bath—chemically pure sulfuric acid; h) water wash combined with mechanical cleaning by passing through sharp sand; i) acid zinc bath at 30°-40°C with the electrolyte containing zinc sulphate, sodium sulphate, and boric acid, maintained at —32° Be. and a pH of 3.5-4.8; j) water wash in cold water followed by hot water at 70°-90° C; k) drying in hot air chambers; and l) rewinding. Hot-dipping was considered superior to electrogalvanizing, in relation to corrosion-resistance, owing to the formation of the iron-zinc alloy layer in the hot-dipping process. Centrifugal machines were employed for stripping excess tin and zinc when coating hollow-ware, and in the case of tin these were operated at 310° C. 7 references are given.—MA.

5.3, 1.8

Coatings (Including Cladding and Bonding): Brass and Chromium Plating. Geo. Patchin and Ernest Brewin (B.I.O.S. Overall Rep. No. 15: Ferrous Metal Industry in Germany, 1939-1945, 217 (1949).

A brief review of German war-time practice. 1) Brass Plating.—In the plating of hard-rolled steel, a coating of copper was first deposited, then a coating of zinc, followed by annealing at 600° C in a controlled-atmosphere furnace, the thickness of the two deposits being so arranged that a 70:30 copper-zinc alloy of 0.0003 in. thickness was produced. The copper and zinc baths consisted of acid electrolytes. The method is recommended because: a) copper and zinc vats are easy to work, whereas alloy brass-plating units are troublesome, and b) after annealing, the deposit is, metallurgically, brass, and is, in effect, brazed to the steel, thereby giving excellent fabricating qualities. 2) Chromium Plating.—A special electrolytic chromium-plating process was employed, in which, after annealing at 1050°-1150° C, the coatings had extraordinary hardness, wear-resistance, and/or corrosion-resistance. 7 references are given.—MA.

5.3, 1.8

Coatings (Including Cladding and Bonding): Tin Coating. Geo. Patchin and Ernest Brewin (B.I.O.S. Overall Rep. No. 15: Ferrous Metal Industry in Germany, 1939-1945, 214-215 (1949).

A brief review of German practice. Separate sections deal with: 1) Tin Coating of Steel (pp. 214-215), cf. previous abstract, and 2) Tin Coating of Cast Iron (p. 215). The procedure adopted was as follows: a) pickle in 10-20% hydrochloric acid; b) dry in sawdust, without previous neutralizing or washing; c) shot-blast with finely crushed grit; d) dip in "killed" spirits of salts; e) dip into molten commercially pure tin at 280°-300° C.; f) remove and re-dip in "killed" spirits; g) dip again in molten tin; h) repeat f) and g) alternately, up to 5 times, to obtain a good, continuous coating; i) dip in water to cool, and j) dip in oil for final protective coat. 3 references given.—MA.

5.3

High Corrosion Resistance Gives Nickel Plated Metals Wide Range of Uses. W. H. Prine, INCO. *Mat. & Meth.*, **30**, No. 6, 43-46 (1949), Dec.

In making industrial equipment, Ni plating can provide an economical solution where service conditions do not justify use of solid corrosion resistant materials. Uses of Ni-plated equipment in paper and pulp, food and beverage, petroleum, textile, and plastic industries are given and illustrated.—INCO.

5.3

Gas Plating. *Prod. Fin.* (Lond.), **2**, No. 7, 60-61 (1949).

A short account of the deposition of metallic films by thermal decomposition of nickel, iron, chromium, tungsten, and molybdenum carbonyls in an inert atmosphere.—MA.

5.3, 6.3

Effect of Copper in Nickel Plating Solutions on Corrosion Resistance of the Plate. *Prod. Fin.*, **13**, No. 8, 68-70-72 (1949) May.

Copper as an impurity in nickel plating solutions reduces the salt spray corrosion resistance of nickel plated steel articles. Its detrimental effect is evident even when chromium is plated over the nickel deposit. An analytical procedure devised by Serfass and Levine appears to be suitable for testing for copper on a production basis. Copper is isolated from the nickel plating bath by precipitation with 2-mercaptobenzothiazole and extraction of the precipiate with amyl acetate. The amount removed is determined by colorimetric techniques.

The salt spray resistance of nickel deposits plated in a Watts type bath was decreased by about 25 percent when the bath contained 10 mg of copper per liter, and by about 50 percent with 50 mg of copper per liter. For an unbuffed 0.001-in. nickel deposit, the relative effect of copper was about the same with or without a superimposed chromium layer. The deleterious effect of copper was evident in platings from three types of nickel plating solutions; one exception occurred with heavier deposits from a fourth type of bath, but reproducible data were difficult to obtain.

Cathode panels of low-carbon, cold rolled, high-finish steel, 2 by 3.5 in. in size, were used. They were cleaned in an alkaline silicate-phosphate cleaner, pickled in 20 percent by volume hydrochloric acid, and plated in thicknesses of 0.0003, 0.001, and 0.0015 in. at 40 amp. per sq. ft. in nickel plating solutions containing 0, 10, 25, 50, 75, and 100 mg of copper per liter. These concentrations were maintained throughout the plating process. Half of the panels which were to be chromium plated were buffed, using a jig to insure identical conditions. The chromium plate was 0.00001 in. for the 0.001 and 0.0015 in. nickel deposits, and 0.000005 in. for the 0.0003 in. nickel deposits. Panels plated in the bath containing 100 mg of copper per liter were not processed further because their appearance would have prohibited commercial use.—PDA.

5.3, 6.3

Hard-Nickel Plating. M. H. Orbaugh. *Metal Fin.*, **47**, No. 11, 53-55+ (1949); also (abridged) *Metal Ind.*, **75**, No. 27, 555-556 (1949).

O. describes the use of nickel deposits, both hard and soft, for engineering purposes such as increasing wear- or corrosion-resistance or the building up of work or mis-machined parts, as distinct from decorative deposits. The advantages of nickel for these purposes compared with chromium are described; they include: a) good all-round physical properties, which can be varied over a wide range; b) more rapid rate of deposition; c) readily machined and ground; d) resistance to a wider range of corrosive media; e) ability to work-harden; f) greater ease of building up thick deposits; g) coeff. of expansion nearer to that of steel; and h) better throwing power of the nickel baths, resulting in a more even deposit. Details are included on the physical properties of the deposits, rate of deposition, composition and operating conditions of the solutions used, and preparation of the base metal. —MA.

5.3

Deposition of Metals on Aluminum by Immersion from Solutions Containing Fluorides. Samuel Heiman, Philadelphia Rust-Proof Co., Philadelphia. *J. Electrochem. Soc.*, **95**, No. 5, 205-225 (1949) May.

A new process was developed for depositing zinc, cadmium, or tin on aluminum and its alloys by chemical displacement. The immersion solutions contain the metal sulfate, hydrofluoric acid or a fluoride, and, in special cases, organic additives. The deposits have good appearance, sound structure, and excellent adherence to the aluminum base. Adhesion does not depend on roughening of the base but is a result of the extreme solubility of the natural aluminum oxide film in the fluoride-containing acid medium, as demonstrated by potential measurements.

The most tenacious of the adhesive bonds, that formed by zinc, exceeds the cohesiveness of aluminum in strength. For this reason zinc deposits may be used as a base on which to plate other metals. Immersion coatings of zinc and tin adhere better than those deposited by the commercial zincate and stannate processes. Copper deposits, whether applied by the immersion technique or by electro-plating, did not adhere well to 2-S aluminum, although some success was attained by using 24 ST aluminum.

Preferred compositions and conditions for deposits on aluminum are:

	Zinc	Cadmium	Tin
Sulfate	5 N	0.035 N	1.5 N (stannous)
Hydrofluoric acid	1 N	0.3 N	2 N
Hydrolyzed glue	...	2 g/liter	1 g/liter
Goulac	...	...	0.2 g/liter
Purified residue acid	...	...	1.3 ml/liter
Duration of dip	30-60 sec	5-15 sec	5-10 sec
Temperature	25 C	25 C	25 C

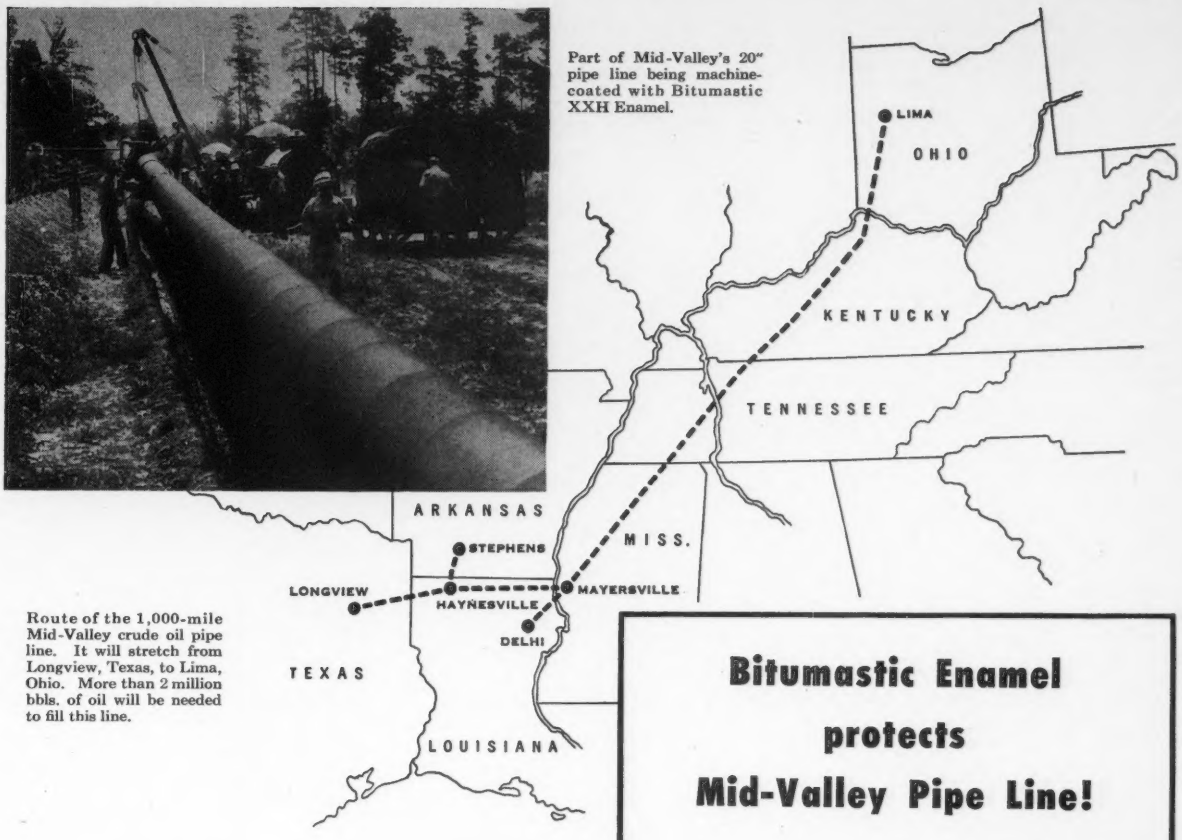
—PDA.

5.3

Electroplated Tin-Zinc Alloy Coatings on Iron and Steel Components. E. E. Halls. *Metallurgia*, **41**, No. 242, 68-73 (1949).

50:50 and 80:20 tin-zinc alloy coatings produced by electrolysis from a composite stannate-cyanide bath are more re-

Part of Mid-Valley's 20" pipe line being machine-coated with Bitumastic XXH Enamel.



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sistant to damp conditions, and solder more easily than zinc and are better for spot welding than cadmium. Comparative corrosion tests are quoted.—MA.

5.3

Protection of Metals by Diffusion of Chromium. Phillippe Galmiche. *Compt. rend.*, **230,** No. 1, 89-91 (1950).

G. describes a process by which smooth, bright coatings can be obtained in a single operation and mixed alloys are formed containing other elements besides chromium, such as aluminum, silicon, and zirconium. The articles are heated in contact with a solid cement consisting essentially of chromium or powdered ferrochrome, alumina, or kaolin, and a halide of ammonia as a vapor above the cement. The reaction on the chromium of the halogen acid arising from the thermal dissociation of the ammonium halide, produces a certain amount of the corresponding chromium halide, whose vapor reacts with the treated metal as iron + $CrF_2 = FeF_2 +$ chromium. The chromium thus produced, being nascent, diffuses continuously into the interior of the metal. The coatings are perfectly compact and bright when the treatment is effected with ammonium fluoride gas. The thickness of the deposit is 0.1 mm after 3 hr. at 1000° C and 0.25 mm after 6 hr. at 1100° C. The diffusion constants of chromium in iron obtained from these determinations were: 2×10^{-4} at 1000° C, 5.3×10^{-4} at 1100° C, and 1.1×10^{-3} at 1200° C, which are greater than the values obtained with solid diffusion, presumably owing to the perfect contact of the nascent chromium with the iron. The chromium coats are more ductile and slightly harder than the base metal and are perfectly resistant to nitric acid at all concentrations. They are also remarkably resistant to dry oxidation, to corrosion by combustion gases, and to thermal shock up to 900° C. They also afford good protection against saline corrosion. The treatment can be applied analogously to different metals. By adding silicon or aluminum or both to the cement the thickness of the cemented film can be considerably increased.—MA.

5.3, 6.4

Silver Plating Process for Magnesium Alloys. Dow Chemical Co., Magnesium Laboratories, Midland, Mich. (Report No. 14704; U. S. Air Material Command, Contract No. W28-099-ac-295) (1948) Apr.

Magnesium alloys can be silver plated after the base metal has been coated first with zinc formed by chemical reduction in an aqueous zinc pyrophosphate bath and then with an intermediate copper electrodeposit to insure adhesion of the conventionally applied silver plate. The silver confers appreciable protection to magnesium alloys both in accelerated salt spray and high humidity tests as well as in outdoor exposure. These siver deposits can be soft soldered without blistering.

A new cleaning procedure before plating eliminates the use of chromium salt which could contaminate the electroplating solution. In this cleaninig method, wrought alloys are pickled in 20% acetic acid—5% sodium nitrate; cast alloys, in 75% phosphoric acid. Following buffing and/or pickling, the parts are cleaned in 9% sodium hydroxide—1.5% trisodium phosphate to remove any pickling smut from unbuffed areas. The exact cleaning procedures as well as the composition of the optimum zinc-plating bath are given in detail.

Copper-silver electrodeposits having a minimum plate thickness of 0.0015 in. withstand at least 24 hr. in 20% sodium chloride spray at 95 F; those 0.002 in. thick or thicker withstand this test for 48 hr. without failure, and for 120 hr. with only slight failure. No failure was observed after 3-mo. exposure to high humidity on copper-silver plates of 0.0015-0.0025 in. combined thickness, except on areas in contact with salt-saturated wooden holding racks. No corrosion was apparent on megnesium plated in the same thicknesses after 3-mo. rural exposure, except for a slight pitting of the silver irrespective of plating thickness. Silver-plated FS-1 (Mg-3Al-1Zn-0.4 Mn) was generally less corroded in a 20% sodium chloride spray after 120 hr. than was M alloy (Mg-1.5 Mn). Increasing the copper-plate thickness does not improve the protective value of the combined copper-silver deposits over that of an equivalent increase in silver thickness. Corrosion resistance of copper buffed prior to applying the silver, or of silver buffed as a final operation, was slightly inferior to that of unbuffed deposits, perhaps because of the amount of metal mechanically removed during buffing.—PDA.

5.3, 3.7

Symposium on Surface Treatment of Metals. I. Electrodeposited Metals. (3) The Structure of Electrodeposits. J. J. Dale, Australian Inst. Metals, Melbourne Branch, Phys. Met. Div. Preprint, **1949,** 7 pp.; also *Metal Ind.*, **75,** No. 17, 355-357; No. 19, 394-395 (1949).

Structure is discussed under the headings: macrostructure, microstructure and crystallography; and metals in the plated, cast, and wrought states are compared. Macrostructural features of electrodeposits described include nodules, pits, treeing, cracks, burnt and laminated deposits. Microstructure is distinguished by preferred orientation of crystals along the direction of growth. Factors controlling the grain-size of deposits are discussed, particularly the effect of addition agents. Photomicrographs illustrate many of these features. Evidence of preferred orientation, allotropic modifications, lattice distortion, and stress in deposits are discussed from the crystallographic viewpoint. Effects of structure on the properties and uses of electrodeposits are described. A bibliography of 29 references is appended.—MA.

5.3, 5.9

Electrodeposited Coatings for Metals. J. L. Bleiweis. *Am. Machinist,* **94,** 147 (1950) Jan. 9.

Purpose, nature of coatings, treatment procedure, notes and comments are given for carronizing and the moly-black process. Corronizing provides a corrosion resistant coating of nickel-zinc, nickel-tin or nickel-cadmium on iron, steel and non-ferrous metals and alloys. The moly-black process produces a deep black, somewhat corrosion resistant, coating of molybdenum and nickel as oxides, on zinc, aluminum, cadmium, tin, nickel and iron or steel.—INCO.

5.3, 5.9

Selecting Economical Inorganic Finishes. J. L. Bleiweis. *Prod. Eng.* (U.S. A.). **20,** No. 10, 146-50 (1949) Oct.

A general review of plated and chemical conversion coatings for copper, ferrous, zinc and lead alloys. Some of the principal finishing processes are tabulated with comments on their economy and utility. The value of zinc and cadmium plating on steel is emphasized.

—ZDA.

5.3

Bright Nickel Plating Provides Low-cost Quality Finish. Jerome L. Bleiweis. *Mat. and Meth.*, **29,** No. 5, 52-55 (1949).

Workshop notes, recommending cleaning, polishing, and plating procedures for producing bright finishes on typical products in various metals and alloys.—MA.

5.3, 3.7, 6.2

The Effect of Titanium (and Silicon) in Iron for Hot-Dip Galvanizing. Heinz Bablik, Franz Götzl, and Rudolf Kukaczka. *Z. Metallkunde,* **40,** No. 5, 176-179 (1949).

A study was made of the effects of additions of up to 3.5% silicon and 1.13% titanium in steel for hot-dip galvanizing. The results show that the rate of reaction between the iron and the zinc increases with increase of silicon up to 0.7% (at which it is some ten times greater than with the silicon-free material), but thereafter the rate decreases; additions of titanium have little or no effect. The presence of either element reduces the pickling attack and hydrogen adsorption on the surface of the steel and, as a consequence thereof, promotes the formation of large, uniform zinc spangles.—MA.

5.3, 3.7, 6.2

On the Importance of the Nitrogen Content of the Iron in Hot-Dip Galvanizing. Heinz Bablik, Franz Götzl, and Rudolf Kukaczka. *Z. Metallkunde,* **40,** No. 4, 141-147 (1949).

A study was made of the effects of the presence of nitrogen on the surface of mild-steel strip, in relation to hot-dip galvanizing, especially by the Sendzimir method. In this process the material is given a light surface oxidation, followed by treatment for 2 min. at 800° C in cracked ammonia, and then is passed directly into the molten zinc without coming into contact with the air. Heavy zinc deposits, up to 350 g/m², are obtained, in which 1/5 to ¼ of the coating is in the form of an alloy layer with the iron. While the hydrogen in the cracked ammonia reduces the oxide on the steel surface, the nitrogen, also present, produces a nitrided layer on the strip, which: 1) increases the solubility of the iron in acids by 3 to 15 times; 2) produces a hard, compact, porous surface on the metal, which gives better adherence of the zinc, as a result of better alloying at the iron-zinc interface; and 3) reduces the rate of reaction between the iron and the zinc, so that the time of hot-dipping must be increased. Photomicrographs show typical structures of cross-sections through the finished material.—MA.

5.3, 1.7

Tentative (ASTM) Specifications for Electrodeposited Coatings of Zinc on Steel (A164-49T). ASTM Specifications and Tests for Electrodeposited Metallic Coatings, **1949,** 1-3.—MA.

5.3, 1.7

Tentative (ASTM) Specifications for Electrodeposited Coatings on Nickel and Chromium, on Zinc and Zinc-Base Alloys (B 142-45T). ASTM Specifications and Tests for Electrodeposited Metallic Coatings, **1949,** 14-17.—MA.

THIS NEW AUTHORITATIVE FIELD MANUAL POINTS THE WAY TO

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5.3, 1.7

Standard (ASTM) Specifications for Electrodeposited Coatings on Nickel and Chromium, on Copper, and Copper-Base Alloys (B141-45). ASTM Specifications and Tests for Electrodeposited Metallic Coatings **1949**, 11-13.—MA.

5.3, 1.7

Tentative (ASTM) Specifications for Electrodeposited Coatings of Nickel and Chromium on Steel (A166-45T). ASTM Specifications and Tests for Electrodeposited Metallic Coatings, **1949**, 7-10. —MA.

5.3, 1.7, 1.6

American Society for Testing Materials. (ASTM) Specifications and Tests for Electrodeposited Metallic Coatings. Sponsored by American Society for Testing Materials and American Electroplaters' Society. Med. 8vo. pp. vii +53, illustrated. 1949. The Society, 1916 Race Street, Philadelphia 3, Pa. ($1.25.) —MA.

• Non-Metallic Coatings & Paints

5.4

Factors Influencing Oxidation of Iron During Firing of Ground-Coat Enamels. R. F. Kimpel and R. L. Cook, University of Ill. Paper before 51st Ann. Mtg. Amer. Ceramic Soc., April 26, 1949, Cincinnati, Ohio. *J. of Amer. Ceramic Soc.*, **33**, No. 2, 57-62, (1950) Feb. 1.

The oxidation of the Fe beneath a ground coat enamel was measured by recording the progressive weight change with a sensitive balance on heating a specimen from room temperature to 1550° F and correcting for the volatile constituents. The oxidation studies indicated that 1) a kaolin clay in an enamel slip allowed less total iron oxidation than a ball clay, since with the latter a more permeable coating developed between 900° F and the fusion temperature, which is believed to be due to either the organic material or the free-silica content of the ball clay, 2) the Ni deposited on the Fe by Ni flashing caused a decrease in the total amount of Fe oxidation, and 3) with low temperature ground coats the rate of metal oxidation was the same as with conventional ground coats up to the fusion temperature of the low-temperature enamel, but owing to the lower fusion temperature the total amount of oxidation was considerably less than with regular ground-coat enamels.—INCO.

5.4

New Industrial Uses for Porcelain Enamel. E. Jones, Ferro Enamel Corp. *Industrial Sheet Metal*, **2**, No. 3, 7-11, (1949) Dec. No. 4, 12-16, (1950) Jan.

Chemical, food processing and textile plants have found in porcelain enamel finish an ideal solution to problems of corrosion, heat and chemical resistance. Now titania-opacified enamels can be applied directly to Ti-stabilized steels. As stainless steels are non-gassing, commercial enamels can be applied to 18-8 stainless steel with satisfactory results. Advantages gained where stainless steel is used for porcelain enamels in place of regular enameling Fe include lighter gage metals may be used, ground coat can be eliminated, and rejects will be minimized by elimination of fishscaling, blistering and copperheading. Stainless steel used in jet engines gets an enamel coating that will withstand temperatures as high as 1800° F. Closely-controlled Ni dip process can be used with inferior grades of steel to insure good enameling qualities of all types. A good Ni deposit improves bonding range of ground coat to the steel; thereby minimizing copperheading and fishscaling by reducing overactive oxidation characteristics. Development of better enamels is also discussed. Corrosion resistant properties of porcelain enamel are also discussed. 33 references.—INCO.

5.4, 6.4

Painting Aluminum. *Metal Ind.* (England), **75**, No. 25, 524, (1949) Dec. 16.

The Tube Investments subsidiary, Drynamels, Ltd., in association with TI Aluminum, Ltd., has developed a process for painting aluminum which introduces a new primer containing acid ingredients, special resins, and a corrosion-resisting pigment. This primer can be applied by brush, spray or roller coating and dries in fifteen minutes, thus eliminating the need for pretreatment equipment.

5.4, 6.4

Bichromated Gelatin Coatings. *Metal Ind.*, Lond., **75**, No. 8, 147 (1949)—*Rail. Eng. Abs.*, **4**, No. 9, 230 (1949).

A note on the protection of metals by use of gelatin made insol. by the "tanning" action of Zn and/or Mn dichromate. The Soln. can be used for dipping Al parts and for painting Al structures provided they are cleaned and degreased. It dries in 15-45 mins. at room temp. and the gelatin coating left becomes insol. in 48 hr.—BNF.

5.4

Principles of Formulation—I. W. G. B. Mills. *Oil Colour Trades J.*, **116**, No. 2663, 1213-4 (1949) Oct. 28.

The first of a series of articles written primarily for students. This instalment outlines the basic principles on which primers for wood, steel, light alloy and cement surfaces should be formulated. Primers for steel surfaces must be corrosion inhibiting; although red lead is stated to be the most widely used, zinc chromate has a superior shelf life and is an efficient corrosion inhibitor. For use on steel surfaces the zinc chromate content should not be reduced with extender so as to fall below 10%.Zinc dust primers are also effective in inhibiting corrosion of steel surfaces. For priming light alloys, zinc chromate is undoubtedly the best inhibitive pigment and it is recommended that it should be used in as high a concentration as possible. The author suggests that alkyds are the best media for metal primers.—ZDA.

5.4

New Developments in Polythene Resins. *Mining J.*, **233**, No. 5956, 967 (1949) Oct. 15.

Alathon, a series of polythene resins for use as coating materials can be used in a variety of industries although development so far is confined to use as coatings by paper manufacturers and converters. They are highly resistant to chemicals and posses high electrical insulating properties. The resins are harder, tougher, non-sticky and capable of imparting a brilliance to papers approaching that of a lacquer finish. Papers coated with them retain flexibility at sub-zero temperatures. A new flame spray method for applying polythene to metal surfaces was developed. Difficulties in applying this plastic to metal surfaces, owing to the high insolubility is overcome by a special spray gun in which the flame is obtained by mixing the fuel gas and the air needed for combustion beyond the torch nozzle. Mfd. by DuPont Co.—INCO.

5.4, 2.3

(1) Evaluation of Adhesion by Ultrasonic Vibrations. (2) The Nature of Adhesion. (1) S. Moses and R. K. Witt. (2) S. Moses. *Ind. Eng. Chem.*, **41**, No. 10, 2334-2338, 2338-2342 (1949) Oct.

1) Determination of adhesion of organic coatings or adhesives to a cylinder, which can be vibrated, by calculation from the frequency and amplitude of vibration at separation. 2) The data obtained by use of this method show that for polystyrene, vinyl acetate/chloride copolymer, or methyl methacrylate, bonded to Al, the adhesion depends on the presence of a fluid, quasi-fluid or mobile state at or near the interface.—BNF.

5.4

A Synthetic Resin for Surface Coating and Filling Irregular Surfaces. C. J. Moss. *Ind. Fin.* (Lond.), 775-783 (1949) July.

A description of the uses and properties of the Araldite series of resins which can be used for filling irregularities in metal surfaces, for the internal protection of collapsible tubes and other aluminum containers, for coating copper wire, and for bonding metals, etc.—MA.

5.4, 8.9

Northrup Develops New Aluminum Primer. K. B. Niles.*The Iron Age*, **165**, No. 5, 90-92 (1950) Feb. 2.

Northrup Aircraft, Inc., has developed an improved type of seal primer for aluminum aircraft parts which is claimed to provide greater corrosion resistance than the conventional zinc chromate formerly used. Surfaces already coated with porous zinc chromate primer which were failing but had not corroded were sprayed with a top coating of fast drying clear synthetic alkyd resin having a medium oil length of not less than 45 percent, of an oxidizing type, such as linseed and tung oil. Tests were conducted on panels of 24ST and 75 ST Dural, 24ST and 75ST Alclad and magnesium for flexibility and resistance to salt spray, sun rays, weathering, and fuel. A new primer was developed to combine the properties of the zinc chromate primer and the additional resin finish. A comparison of different blends tested is tabulated. Tests are described and results given for the different finishes used. The blend chosen for best overall qualities is composed of the following ingredients: non-volatile, total 49.5, volatile, total 50.5; pigment to vehicle solids; pigment 53, vehicle 47. The resulting new primer is called Northrup Seal Primer No. 75. It is equivalent or slightly superior in flexibility, and its resistance to softening under moisture conditions was better than conventional zinc chromate primer. The new primer gave considerably more protection in salt spray corrosion exposure, improved appearance, greater film strength, and less porosity. Adhesion of other aircraft

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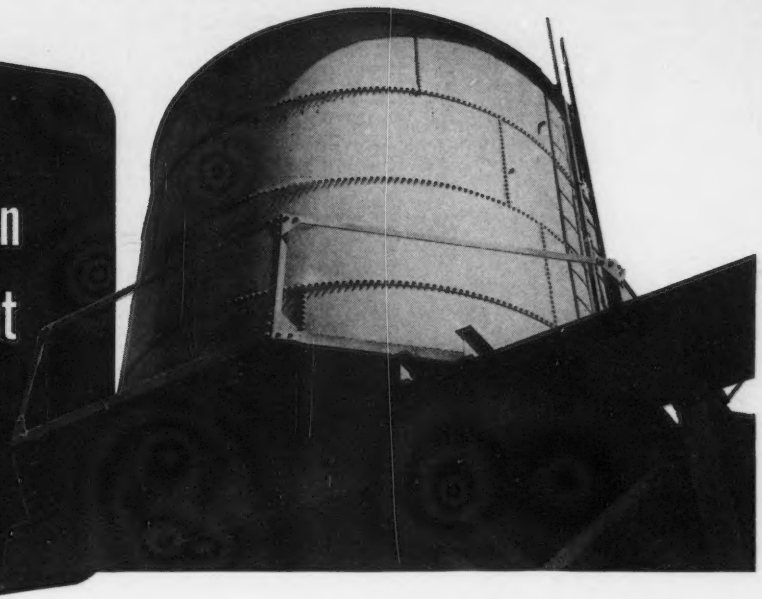

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finishes was greater than with zinc chromate primer, and better gloss was achieved in lacquer or enamel coatings. —ALL.

5.4, 3.3

Fungicidal Treatment of Paints—Australian Defense Res. Labs. Circular No. 12; *Oil Col. Trades J.*, **116,** No. 2658, 874 (1949).

Lab. tests show that Ph mercuric acetate (P.M.A.) (0.05%) or salicylanilide (1%) improved resistance to fungi in paint. Other workers have also shown P.M.A. to be effective in concentrations of 0.02% and upwards. Hg naphthenate has also been recommended. Mercurials are suggested as being most effective for the protection of insulating lacquers, while salicylanilide is probably more effective in the case of vegetable fats and waxes.—BNF.

5.4, 7.2

Polyken Corrosion Protection Coating. *Oil & Gas J.*, **48,** No. 39, 78-79 (1950) Feb. 2.

Polyken is an oriented polyethylene film with a synthetic adhesive applied to one side for pipe coatings. It has electrical and chemical resistant properties. An exclusive calendar orienting process gives it elasticity and greater strength than other forms of polyethylene, so as to maintain a permanent pressure around the pipe and thus prevent a flow of moisture between the tape and the protected metal. Mfg. by Bauer and Black.—INCO.

5.4, 1.7

Emulsion Paints. Henry F. Payne. *Paint, Oil and Chemical Re.*, **112,** 12+ (1949) Dec. 8.

A survey made by Technical Sub-Committee 44 of New York Paint and Varnish Production Club on available technical literature on emulsion paints and materials used in their manufacture. 43 ref.—BLR.

5.4

Preventing Defects in Enameling Holloware. F. A. Petersen, U. of Ill. *Ceramic Ind.*, 55-56 (1950) March.

Some of the characteristic defects in grayware enamel are pointed out. Insufficient mottling occurs when the drying process of the enamel is carried out too rapidly. Slow drying causes excessive rusting and the development of a very coarse mottle. It is therefore very important to obtain the right speed in the drying process. The final fired appearance of mottled grayware is not only a function of the drying process and the base metal, but it is affected by every operation in the enamel shop. Careful handling of the metal shape prior to enameling is of great importance since any marking of the metal can be the cause of irregular and improper mottling in the marked area. The most effective method used to develop bond in grayware enameling is the use of iron-sulfide additions to the acid pickle. This chemical causes a deep etching of the steel base. A very thin coat of enamel will lead to the development of poor contrast between the background and the mottle, and it will also cause the ware to be very dark in color. Too heavy a coat will cause the same poor contrast and a relatively light-colored ware.—TDD.

5.4, 5.9

Evaluation of Present-Day Protective-Coating Systems for Steel and Concrete. A. F. Pistor. *Off. Bull., Arizona Sewage & Water Works Assoc.*, **8,** 30-43 (1948). *U. S. Pub. Health Eng. Abs.*, **28,** No. 7, 30 (1948). *Chem. Abs.*, **43,** No. 17, 6835g (1949).

Coatings commonly used for the protection of steel and/or concrete above and below water are classified as: 1) bituminous coatings; 2) linseed-oil paints; 3) oleo-resinous enamels; 4) alkyd enamels; 5) chlorinated rubber enamels; 6) vinyl copolymer enamels. Each type of coating is described, with mention of general comp. characteristics and most suitable application methods. The mechanism of corrosion of steel is discussed briefly and suggestions are offered for the initial prep. of a surface to obtain most satisfactory results from the protective coating applied.—RPI.

5.4, 2.3

Paints for Enclosed Structural Members in Steel Housing Construction. H. A. Pray and R. S. Peoples. *Iron Age* (U. S. A.), **164,** No. 16, 63-70 (1949) Oct. 20.

A report on prolonged laboratory tests of 34 paint systems to find which were best for protecting the inner surfaces of cavity steel walls, on which much condensation is likely to occur. The paints were tested under continuous immersion in distilled water; in contact with air at high humidity; under continuous condensation; under alternating wet and dry conditions; and in continuous contact with insulation in the presence of water. The test panels were examined with intact coatings and with scratch lines to simulate damage. They were judged solely on the protection given, appearance being unimportant. Continuous immersion was the most corrosive condition, and paints containing red lead, zinc chromate or both behaved best, followed by asphaltum-type paints and those containing other zinc pigments. Red lead and zinc chromate were also the best pigments for preventing blistering when in contact with neutral or alkaline insulating material.—ZDA.

5.4

Lead Cyanamide, New Anti-Corrosive Pigment. N. Kopyloff. *Peint. Pig. Vernis*, **25,** No. 4, 144-5 (1949).

Lead cyanamide has a higher oil absorption and covering power than red lead. Paints based on lead cyanamide dry more slowly, are a little more elastic and give better corrosion protection as compared with those based on red lead. Lead cyanamide is suggested as a substitute to relieve the shortage of red lead.—RPI.

5.4

Research on Limiting the Number of Procedures for One-Coat Paint. M. Kronstein and C. J. Marsel. U. S. Dept. of the Army, Contract No. W36-039-sc-32250 (1948), Quarterly Report No. 8; *Prev. Det. Abs.*, **1949,** 7, Lac 27.

This report is a summary of the progress made during a 2 yr. study on the possibility of limiting the number of paint applications necessary to produce a successful coating. The work is summarized under the following headings: 1) basic research on the progress of drying, 2) drying paint films with light energy, 3) the electrographic printing method, 4) further tests on panels and paints, 5) application of new methods in the development and evaluation of coatings, 6) improvements in paint testing facilities in the lab., 7) studies on adhesion, 8) bibliography.—RPI.

5.4

Reactivity of Zinc Oxides. H. A. Laurie and D. K. Box. *Paint Notes* (Australia), **4,** Nos. 7-8, 246-51 (1949) July-Aug.

The authors review the literature on the effect of the reactivity of zinc oxide on the weathering properties of paints, and conclude that there appears to be little experimental evidence to support the various opinions expressed, except for the work by Dunn on zinc soap formation. The authors' own work on this subject suggests that, in general, direct process oxides have low reactivity and good chalking resistance; whereas, indirect process oxides with relatively high reactivity exhibit poor chalking resistance. There are exceptions to this generalization; acicular zinc oxides are fairly reactive, but show good resistance to chalking.—ZDA.

5.4, 6.4, 5.9

Non-Blister Bake Finish on Aluminum Castings. A. P. Lehmann. *Ind. Fin.*, **24,** No. 8, 51-52 (1948).

L. discusses the causes of blistering of baked-on finishes applied to aluminum castings and shows that absolute cleanliness of the metal surface is essential for elimination of trouble. Blistering does not occur in finishes applied to sand- or shot-blasted castings, as in these cases the surface pores have been closed. With castings which have not been subjected to this treatment a special priming treatment is called for. A suitable method of scaling the pores is described.—MA

5.4, 6.4

The Painting, Enamelling and Lacquering of Light Metals. *Light Metals* (England), **13,** No. 144, 32-37 (1950) Jan.

The requirements and procedure for the successful application of applied coatings to aluminum, magnesium and their alloys are surveyed. Attention is directed to the difference between light alloys and heavy non-ferrous metals and steel with respect to painted coatings and the necessary cleaning procedures. Extensive details of these procedures are given.—ALL.

5.4

Film Formation, Film Properties, Film Deterioration. J. S. Long. *Off. Digest* (U. S. A.), No. 207, 648-98 (1949) Oct.

A comprehensive discussion on some of the properties of films produced by the oxidation of unsaturated esters, with special reference to the destructive influence of ultraviolet light and water. After dealing at length with the chemistry of film formation and drying, and the mechanical properties of films, the author discusses the deterioration of paint films and advances new data on water absorption by paints containing various pigments, including zinc oxide. Data are also included on the ultra-violet transmission of a series of unpigmented films. This quantity is seen to be related to the known durability of the materials on exterior exposure, and it is suggested that such measurements will be of use in assessing new resins, etc. Finally, a program of research into the properties of 21 pure film-forming compounds is outlined, with notes on the preparation of the specimens.—ZDA.

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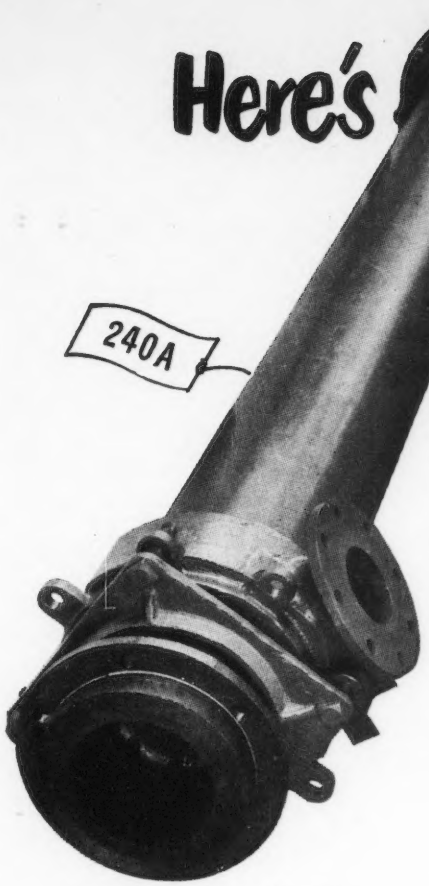

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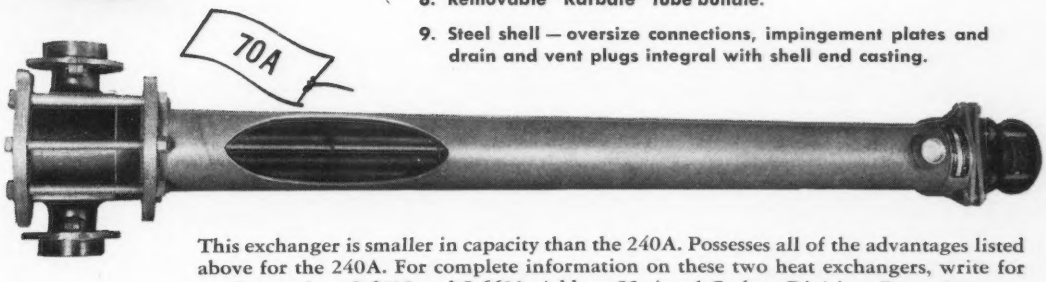

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5.4, 4.1

Protective Coating. *Machine Des.* **21,** No. 10, 138 (1949) Oct.

Tygon series K self-priming paint which adheres tightly to metal, wood, or concrete is recommended as protective coating to resist corrosive conditions not sufficently severe to warrant use of multiple coat treatment. It has high resistance to corrosive fumes of almost all acids and alkalies as well as excessive humidity, grease, oil, and alcohols.—INCO.

5.4

Plastic Protective Coating for Metal, Wood and Concrete. *Machinery,* **56,** No. 7, 163 (1950) Mar.

New paint coating, designated Series K, is a self-priming vinyl-base paint that adheres tightly to metal, wood or concrete. It was developed primarily to fill the need for an easily applied protective coating to resist corrosive conditions not sufficiently severe to warrant the use of multiple coats. For normal conditions, 2 or 3 coats of the new paint provide effective and long-lasting protection. It shows excellent resistance to corrosive fumes of almost all acids and alkalies, as well as to excessive humidity, grease, oil, and alcohols, but is softened by aromatic hydrocarbons, ketones, and esters. This paint is non-oxidizing, non-inflammable when dry, and possesses an upper temperature limit of about 200° F. Mfd. by U. S. Stoneware Co.—INCO.

5.4, 7.5, 6.2

Linings for Steel Shipping Containers. L. F. McKay. *Chem. Eng. News,* **27,** 3694-3697 (1949) Dec. 12.

Outlines methods and preliminary results of research program sponsored by Steel Shipping Container Institute at Battelle Memorial Institute. Effect of surface conditions on coatings performance was investigated by automatically spraying measured thicknesses of representative and widely used commercial coatings onto the various surfaces and then placing the coatings in contact with corrosive chemicals in test cells.—BLR.

5.4

Sprayed "Envelopes" Protect Aircraft Skin. *Aero Digest,* **1949,** pp. 38-39, Dec.

Every manufacturer of aircraft assemblies utilizing aluminum-alloy skins is plagued by surface damage invariably accumulated by a sheet from the time it enters the plant as stock until it is eventually riveted or otherwise joined to the assembly of which it becomes a part. Better Finishes and Coatings, Inc., appears to have provided an answer to the problem by use of its Liquid Envelope, a protective plastic coating which is sprayed upon the surface before fabrication and which is peeled off upon completion of the assembly. The material air-dries fit for handling in from 5 to 10 min., or can be cured faster by applying heat. It can also be used for surface protection on stainless steel, clad, plated, or prefinished materials during fabrication, storage, testing, and shipping.—TDD.

5.4, 3.3

Anti-Fouling Paints (Studies in Multiple Pigmentation). Allen L. Alexander and R. L. Benemelis. *Ind. and Eng. Chem.,* **41,** No. 7, 1532-1535 (1949).

The data obtained indicate that antifouling paint formulations may be extended by replacing primary toxic pigment with certain inert materials under specified conditions without materially affecting the paints' ability to prevent fouling attachments, except that the inert material must be selected in accordance with its compatability with the toxic. Metallic copper pigments should be avoided in conjunction with other metallic pigments as inerts, owing to the danger of inactivating the copper, particularly at high pigmentations. Simultaneously accelerated corrosion of the second metal usually results in the complete destruction of the paint film. Metallic powders, such as zinc dust, may be used to fair advantage with mercury and copper oxides and with mercurous chloride. At equal volume concentration, mercuric oxide provides more lasting protection than copper.—MA.

5.4, 2.1

Accelerated Weathering Tests and Chalking of Zinc Oxide Paints. W. Griffiths. *Paint Notes* (Australia), **4,** Nos. 7-8, 237-46 (1949) July-Aug.

Zinc oxide chalking appears to be a more serious trouble in Australia than in the U. S. A. or England, owing, it is suggested, to the severity of the Australian climate. This chalking is accentuated by water on the paint film. The author claims for the "Weatherometer" that it gives reliable and reproducible results on the chalking of zinc oxide which agree with those obtained for natural weathering tests. The accelerated tests described by the author give similar results to the outdoor exposure tests described above. The opinion is expressed that a uniform moderate particle size zinc oxide seems to be the most suitable for exterior paint films.—ZDA.

• Packaging

5.6, 5.8

Impregnated Latex Coatings Prevent Corrosion of Metals. *Prod. Eng.* **20,** No. 6, 175-176 (1949) June.

Wrapping materials impregnated with sodium benzonate not only exclude humid or polluted atmospheres, but also prevent attack on the underlying metal if the wrapping becomes defective. The first wrappings investigated were cellulosic materials. A recent promising development involves the use of sodium benzonate as an additive to rubber latex.

Latex containing sodium benzoate, applied at normal temperature to small articles by dipping and to large ones by spraying, gives a protective anticorrosion coating of desirable mechanical properties. The coating covers the surface completely, yet can be readily peeled off when no longer needed, especially if stripping tape is included in the coating.

Sodium benzoate is a safe inhibitor, i.e., it does not induce corrosion or localized pitting if its concentration falls below the inhibiting percentage. In addition, it is resistant to mold growth and compatible with many organic substances.

PDC Comment: The usefulness of sodium benzoate and of soluble benzoates in general as anticorrosive additives and freezing point depressants has been described by William H. J. Vernon *et al.*—PDA.

5.6

Canning Small Arms. R. J. Hassett. *Ordnance,* **1950,** 352-353, Mar., Apr.

A "canning" method was developed which assures serviceable weapons—free from rust and fungi and ready for immediate use. The drum-type container developed for packaging M1 rifles, carbines, pistols, Browning automatic rifles, and sub-machine guns is fabricated from low-carbon steel (WD 1015). The shell is of 18-gauge material and the end-covers are of 14-gauge. The container is hermetically sealed; the atmosphere in the container is controlled at a low relative humidity by means of several pounds of moisture-absorbing material. Methods of preparation for packaging of the various types of weapons are outlined. Drop and air transportation tests were conducted and the results indicated that although the containers were badly dented, they retained their hermetic seal and the weapons were not damaged in any way. Most of the models when packed will float and support a load of approx. 150 lbs.—TDD.

5.8, 6.2

Adsorption Passivation of Iron by Protein Films. (In Russian.) G. S. Koshurnikov. *Zhurnal Prikladnoi Khimii* (J. of Applied Chem.), **22,** 698-702 (1949) July.

Tabulated experimental data indicate that gelatin-nitrophenol adsorption layers passivate iron in the presence of acid solutions and that casein-phosphate adsorption layers passivate it not only in the presence of acid but also in the presence of aggressive salt media. 10 ref. —BLR.

5.8, 5.4

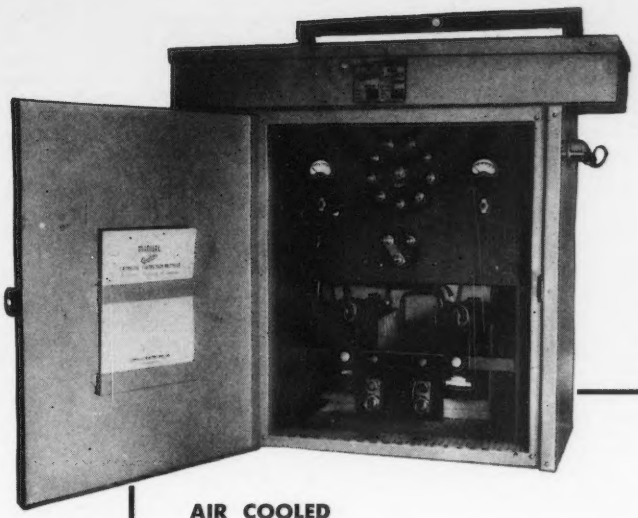
Passivation of Iron by Adsorption-Paint Coatings. (In Russian.) G. S. Koshurnikov. *Zhurnal Prikladnoi Khimii* (J. of Applied Chem.), **22,** 809-811 (1949) Aug.

Investigation of above shows that chemically adsorbed layers passivate iron in acid media. Mechanism of passivation is postulated. Passivating effect may be increased by covering the adsorbed layers with polymerizable lacquers.—BLR.

5.8, 8.4, 8.9, 4.4

Corrosion Inhibited Fuels. J. M. Michel and K. F. Hager. *Ind. Eng. Chem.,* **41,** No. 11, 2616-2622 (1949) Nov.

A survey on already known methods and recent advances in the field of corrosion prevention in pipe lines, storage containers, tanks, and other equipment in contact with fuels, even under severe conditions, e.g., in presence of sea water. Of the three possibilities—proper choice of corrosion-resistant construction materials, surface protection of metals or alloys in question by suitable treatment, and admixtures to the fuel in order to produce surface passivity—only the third method promises an extended technical application and sufficient endurance in practical use. Research in this field starting in the middle of the 1930's is reported, particularly with regard to prevention of use of F cartridges of dangerous corrosion by fuel containing tetraethyl-lead of light metal tanks in airplanes. Further development stimulated by extensive investigations on emulsifying agents led to the surprising result that, without regard to the construction materials used, even a small addition of Mepasin - sulfamido - acetic acid-Na salt to the fuel prevents any corrosion. These results present a prospect of solving many corrosion problems, starting at the oil well and ending with



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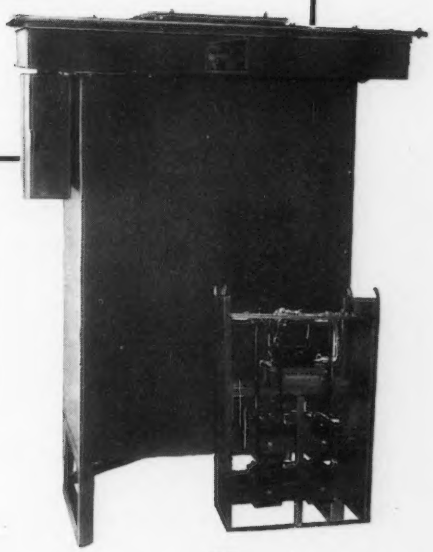

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the last fuel consumer, by the simple addition of the smallest amount of such chemicals. 54 references.—INCO.

5.8, 4.6

Corrosion Inhibitors for Steel. W. G. Palmer. *J. of the Iron and Steel Inst.*, **163,** 421-431 (1949) Dec.

Presents and discusses experimental results which show that many inhibitors, added to water or chloride solution in amounts insufficient to completely stop attack, produce localized attack, which is more intense than the corrosion in the absence of an inhibitor. Inhibitors which are free from this danger are, in most cases, inefficient. It is believed that the attack is caused by formation of blister-like membranes over the sensitive points, which prevent access of inhibitor to the places where required. By using suitable mixtures of phosphate and chromate (or phosphate and persulfate), so that the substance precipitated will not be ferrous, but ferric phosphate (a crystalline non-membranous body), the danger can be avoided. Includes "Foreword" by U. R. Evans.—BLR.

5.8, 8.9

Rust Inhibitor. *Petro. Ref.,* **29,** No. 1, 185 (1950) Jan.

A new rust inhibitor for light oil products in pipe lines and static storage, Santolene C is a hydrocarbon-soluble, water-insoluble, non-metallic organic material and is intended to be used in such products as gasoline, fuel oil and kerosene. It is sufficiently effective at a dosage of 0.002% by wt. when tested according to modified ASTM test against distilled water. Concentrations up to 0.01% may be needed against sea water. Mfd. by Monsanto Chemical Co.—INCO.

5.8, 4.6

Use of Sodium Benzoate. *Can. Chem. Process Ind.*, **33,** No. 11, 960 (1949) Nov.

The use of sodium benzoate as an antifrigerant and as a corrosion inhibitor in heat exchange systems is discussed.—INCO.

5.8, 5.9

Emergency Acid Inhibitor for Acidizing Treatments. F. Gibadlo, Process Chemical Specialties. *Chemical Eng.*, **57,** No. 1, 122 (1950) Jan.

When acid-cleaning a batch of iron or steel, an effective impromptu acid inhibitor can be made by treating concentrated sulfuric acid with gas oils or various grades of light fuel oils. Mineral oils possessing a min. of unsaturates are preferable. The acid and oil are agitated together for 10-15 min. in a glass or other acid resisting vessel, at a temperature preferably below 40° F. The layer of unreacted oil at the top is decanted and discarded, or the bottom layer of inhibited sulfuric acid can be separated in a separatory funnel. Amount of oil-acid mixture used is 5% or less.—INCO.

5.8

The Adsorption of Long-Chain Polar Compounds from Solution on Metal Surfaces. E. B. Greenhill. *Trans. Faraday Soc.*, **45,** No. 7, 625-631 (1949).

The adsorption isotherms of long-chain polar compounds on metal powder have been determined. The results show that saturation of the surface, giving a unimolecular layer, occurs at very low concentrations with strongly adsorbed substances such as stearic acid, whereas alcohols and esters require much higher concentrations. Although the initial rate of adsorption from solution is very rapid, final equilibrium may not be reached for many hours. The adsorption process appears to be the same for thoroughly cleaned and reduced powders as for oxide-coated powders. With the clean powders, however, the amount of adsorption is increased in some cases owing to an increase in the surface area brought about by the reduction and degassing procedure at 200°-250° C. A comparison is made of the adsorption results and the boundary lubricating properties of acids, alcohols, and esters. There is some discrepancy in the behavior of the alcohol, since it is more readily adsorbed on metal powders than the ester, whereas it appears to possess poorer lubricating properties. With the fatty acid and ester, however, there is close agreement between the frictional behavior and the adsorption measurements. The fatty acid, which is more readily adsorbed (and which may react to form the metal soap) is a more effective boundary lubricant than the ester.—MA.

• Surface Treatment

5.9, 5.3

Surface Preparation of Mild Steel. W. A. Johnson. *Iron and Coal Trades R.*, 1177-8, 1949, Nov. 18. *Engineer,* **188,** 589-591, 1949, Nov. 18.

A summary of a paper presented to the Institution of Mechanical Engineers. After pointing out the need for adequate surface preparation before painting, the author outlined the methods available, viz.: weathering, and wire brushing, pickling, phosphating, flame-cleaning and shotblasting. In discussing primers for protecting steel for limited periods to cover transit, fabrication and erection, the author claimed that there was no satisfactory primer available, as red lead presented difficulties when welding through it. Zinc and aluminum coatings are advocated for the protection of mild steel in bulk and it is suggested that aluminum provides cheaper coverage, but no mention is made of the merits of the two metals; both galvanizing and spraying are mentioned as methods of applying zinc coatings. The author has drawn up a table of average costs of various surface treatments for their application and maintenance for 50 years. —ZDA.

5.9

Economic Considerations in the Employment of Sand-Blasting. H. Kalpers. *Metalloberflache,* **3,** No. 3, 66-70 (1949).

K. discusses the economics of sand-blasting in relation to: 1) internal dia. of the nozzle and the throughput of sand at various air pressures, 2) the use of chilled cast-iron nozzles with and without internal linings of tungsten carbide, and 3) the use of nozzles which are suitably designed for the job on hand, i.e., specially shaped nozzles for sand-blasting the internal surfaces of hollow articles such as tubes and drums.—MA.

5.9, 2.2, 3.7

Electrolytic Polishing of Metallic Surfaces—IV.-V. Conclusion. Pierre A. Jacquet. *Metal Fin.*, **47,** No. 9, 60-67; No. 10, 68-73 (1949).

The application of electrolytic polishing to the physical chemistry of metals is briefly described, and its advantages over conventional methods are indicated. The effect of polishing solution and technique on electron-diffraction patterns is described, and it is claimed that electron-diffraction examination shows that an electrolytically polished metal surface has the normal structure of the metal and is practically free from chemical impurities. The optical and crystallographic properties of electrolytically polished surfaces are mentioned, and the diffraction and diffusion of X-rays are also briefly discussed. The effect of method of polishing on the solution potential of the metal is described. The formation of cathodic deposits on electrolytically polished surfaces is considered, and it is concluded that this method of polishing makes possible the study of thin deposits and shows phenomena of practical interest, such as the influence of the composition of the bath, the conditions of electrolysis, the effect of superficial impurities on the formation of the first seeds, crystalline continuity, and adhesion. (V.) It is claimed that many investigators of the corrosion, oxidation, and passivation of metals have failed to recognize the tremendous influence of the initial state of the surface of their samples on the results obtained. Mechanical polishing and chemical etching may result in the microgeometric and physico-chemical characteristics of the surfaces being poorly defined and not reproducible. A number of examples are quoted where wide differences have been obtained between surfaces electrolytically polished and those mechanically polished. Electrolytically polished aluminum is less readily attacked by HCl and by NaOH than if it is mechanically polished. Similarly, in the salt spray, 99.90% aluminum will remain bright after a 120-hr. exposure if it has been electrolytically polished, but a mechanically polished specimen is covered by a thick crust of oxide. Similar phenomena are observed in the atmospheric tarnishing of brass. Electrolytically polished metals also behave differently during high-temp. oxidation and under passivating conditions. Surface condition also influences ion-exchange phenomena, electron emission by metals, their magnetic properties and surface electrical conductivity.—MA.

5.9, 3.7

Electrolytic Polishing of Metallic Surfaces—Conclusion. P. A. Jacquet. *Metal Fin.*, **48,** No. 2, 55-62 (1950) Feb.

Among the advantages of electrolytic superfinishing is the improvement of resistance of steels to corrosion. Electrolytic polishing is discussed as an intermediate stage in manufacturing. Bibliography for parts III-VII includes 242 references.—INCO.

5.9

Finishing Automotive Die Cast Parts. Herbert Chase. *Iron Age,* **164,** 89-91 (1949) Nov. 3.

Tells how high production rates for finishing zinc-alloy die-cast automotive parts are maintained through use of tumbling and blasting equipment to remove flash and burrs, while a conveyorized automatic unit is utilized for dichromating parts to inhibit corrosion. Illustrates equipment of Rochester Products Div., General Motors Corp.—BLR.

5.9, 1.4

Metal Cleaning Bibliographical Abstracts. J. C. Harris. ASTM Special Tech. Pubn. No. 90, 1949, 68 pp. Published by

the Society, 1916 Race Street, Philadelphia 3, Pa. $2.75.

This publication supersedes the earlier bibliography of Harris and Mears (mainly on aluminum cleaning) published in ASTM Bulletin, May 1944, No. 128, pp. 35-40. It gives 494 references on cleaning, pickling, corrosion inhibitors, etc., together with short abstracts. Several of the abstsacts are taken from *Chem. Abs.* or from *Met. Abs.* (which is incorrectly referred to as *J. Inst. Metals*). The references are classified firstly by year, secondly by author; they are indexed by subject, author, standard specifications, and patents.—BNF.

5.9

Application of the Radioactive-Tracer Technique to Metal Cleaning. J. C. Harris, R. E. Kamp, and W. H. Yanko. *ASTM Bull.*, **1949,** No. 158, 49-52.

The efficiency of detergents or cleaning methods can be studied in the laboratory by soiling a clean specimen with an oil and estimating the residual oil after cleaning by: i) weighing, ii) examination with ultra-violet light (having incorporated a fluorescent substance in the oil, iii) a water-break method, or iv) electrodeposition. All these methods have deficiencies. A new method is described in which nn-di-n-butyl stearamide (I) containing a C^{14} atom was mixed with the oil, C^{14} being a soft β-emitter with a half-life 5300 years. Mild steel or stainless steel panels 1 in. in dia. were covered with a definite quantity of oil containing 1% I. The radioactivity was measured with a Geiger-Muller counter before and after cleaning. It is claimed that about 10^{-9} g/cm.^{2} of residual oil can be detected by this method, while the limit of sensitivity with a gravimetric method is usually about 10^{-4} g/cm.^{2} Indications were obtained, however, that I was preferentially adsorbed on the metal surface and so separated from the oil. A satisfactory addition should not behave in this way.—MA.

5.9, 3.7

Surface States and Corrosion of Metals. (In French.) P. A. Jacquet. Assoc. Ital. di Metallurgia, 2nd National Conference (1948) May.

(Typescript, 21 pp.) Principles of electropolishing; improved corrosion resistance of electropolished Al and brass, and nature of natural oxide film; review of applications of electropolishing to corrosion research.—BNF.

5.9

Phosphate Treatments for Iron and Steel Surfaces. H. A. Holden. Paper before Northampton Polytechnic lectures on Aspects of Metal Finishing. *Electroplating*, **3,** No. 6, 213-214; No. 7, 244-245+ (1950) Feb., Mar.

Lecture deals with phosphate coating in general, chemistry of the phosphating process, method of treatment, thick and thin coatings, and special processes such as zinc flash Bonderizing process, application by spray gun, tube drawing, parco-lubrizing, bonding sprayed metal to phosphate coatings and cold phosphating.—INCO.

5.9

Chemical Polishing of Metal Products. Russell L. Deubner. *Finish*, **6,** 19-20 (1949) Dec.

Briefly describes and illustrates new process developed at Battelle Memorial Institute by which metal products can

Expert says CORROSION costs as much as taxes!

With this dramatic exposé, H. H. Anderson, former Vice-President of the National Association of Corrosion Engineers, emphasized the high cost of corrosion in industrial equipment. He was speaking at a regional meeting of the Association held recently in Houston, Texas. He stated that corrosion costs American industry at least **5½ billion** dollars annually—**as much as** the estimated increase in federal income taxes for 1951 over 1950.

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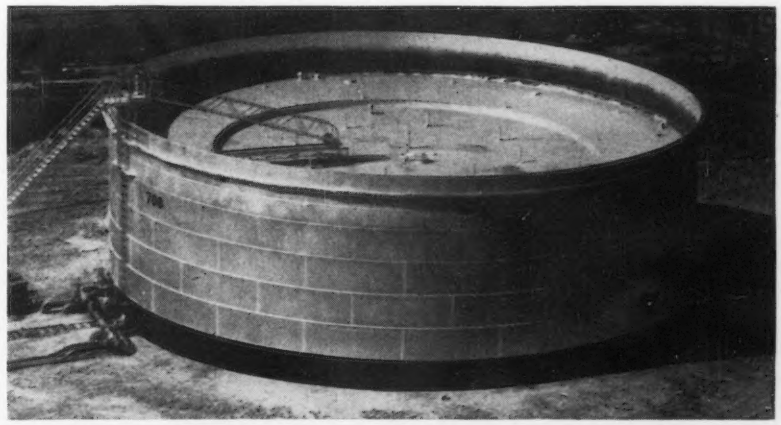

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Detroit 26 . . . . . 1561 Lafayette Building
Havana . . . . . 402 Abreu Building
Houston 2 . . . . . 2159 National Standard Building
Los Angeles 17 . . 1552 General Petroleum Building
New York 6 . . . . . 3328—165 Broadway Building
Philadelphia 3 1661-1700 Walnut Street Building
Salt Lake City 4 . . . . 563 West 17th South Street
San Francisco 4 . . . . . 1572—200 Bush Street
Seattle 1 . . . . . 1363 Henry Building
Tulsa 3 . . . . . 1640 Hunt Building

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19a

be given a bright, reflective surface without mechanical or electrical operations. The product is merely dipped into a chemical solution. When withdrawn a few minutes later, it is polished to a smooth, highly reflective luster. Major advantages are simplicity and non-etching character of the solution. Metals to which the process is applicable include brass, copper, nickel, silver, Monel, and aluminum.—BLR.

5.9, 6.4

A Survey of Some Specialized Aluminum Alloys for Anodic Treatment. J. F. G. Herenguel. *Sheet Metal Ind.*, **26,** No. 268, 1739-1743 (1949).

Surface defects arising during anodic treatment may be of mechanical or metallurgical origin. The latter concerns the chemical composition and physical structure of the metal or alloy. Two specialized alloys have been developed in France. They are based on high-purity aluminum and magnesium (99.95% at least) and containing 3 and 5% magnesium, respectively. The properties of these alloys are considered and the precautions necessary in anodizing them are stated.—MA.

5.9

Heatless De-Greasing in 10 Seconds by Ultrasonic Waves. *Factory Management and Maintenance,* **107,** 130 (1949) Nov.

Shows how an ordinary caustic cleaning solution can remove either heavy or light grease from steel parts in 10 sec. by use of ultrasonic vibrations.—BLR.

MATERIALS OF CONSTRUCTION

• Ferrous Metals and Alloys

6.2

Production of Stainless Steel. Parts I-III. B. H. DeLong. *Steel,* **125,** 64+, 132+, 102+ (1949) Oct. 31, Nov. 7, Nov. 14.

Part I outlines history of development; manufacture of stainless-steel ingots; melting and refining practice; forging and rolling; pickling; electropolishing; and wire drawing. Equipment is illustrated. Part II considers types and causes of corrosion encountered in service. Steels are divided into 3 groups and data are tabulated. Part III describes the various types of stainless steel together with a discussion of their physical properties, fabrication considerations, and indicated uses.—BLR.

6.2

Corrosion. M. G. Fontana. *Ind. Eng. Chem.*, **41,** No. 11, 83A-84A (1949) Nov.

Effects of oxidation resistance of alloying iron, titanium and molybdenum with chromium in stainless steels and other materials are discussed.—INCO.

6.2, 6.7

Corrosion. M. G. Fontana. *Ind. Eng. Chem.*, **42,** No. 1, 67A-68A (1950) Jan.

Recent developments in nodular cast iron are briefly described as well as in fluorinated polymers, such as Teflon and Kel-F.—INCO.

6.2

Present Knowledge of Low-Carbon 18-8. H. W. Gillett, Battelle Memorial Institute, Columbus, Ohio. ASTM Preprint, 22, 14, 1949.

Data reported in the literature on austenite stability, carbide precipitation, weldability, and corrosion resistance of low-carbon 18-8 chromium-nickel steel are reviewed.

A bibliography of 46 references is included. Both carbon and nitrogen content must be impractically low to make 18-8 steel absolutely resistant to participation and grain boundary corrosion under any and all conditions of sensitization and attack. This absolute resistance is not required under most conditions of service. Commercially obtainable low carbon and moderate nitrogen contents seem adequate to prevent sensitization on cooling from welding under usual usual conditions, but evidence for this is chiefly indirect.

Artificial, conventional methods for evaluating sensitization and corrosion resistance are inadequate for accurately appraising the ability of the material to perform a given service. Specifications calling for such tests may cause satisfactory material to be rejected.—PDA.

6.2, 3.5

Attack of Hydrogen - Nitrogen Mixtures on Steels at 13,000 to 15,000 Pounds Per Square Inch Pressure and 204° to 593°C. Harry K. Ihrig. *Ind. and Eng. Chem.*, **41,** 2516-2521 (1949) Nov.

Above attack was studied for various steels. Results are tabulated and illustrated by photographs and micrographs. It is believed that the austenitic chromium-nickel stainless steels are best for use at high pressures of hydrogen and nitrogen. However, it is recommended that samples of these steels be removed after periods of operation to determine whether attack has been progressive.—BLR.

6.2

Rustfree Steel Developed. *Industry & Welding,* **22,** No. 12, 61 (1949) Dec.

New electrosteel alloys, known as Super Rustfree Steels, have improved chemical and corrosion resistant properties, even against aqua regia, as compared with stainless steel and the best known high nickel-molybdenum alloys. All grades of SR steels can be melted in electric arc and induction furnaces from readily available raw materials and are not sensitive as to carbon content. Weldbrazing is the name given to the new welding method which improves the weldmetallurgy of steels in general. Based on the discovery of a new type of bond, it combines advantages of fusion welding and brazing without the disadvantages of either. It may be used in joining and building up without fusion both ferrous and non-ferrous metals and alloys. Developed by Uniworld Research Corp. of America.—INCO.

• Non-Ferrous Metals and Alloys—Heavy

6.3

The Oxidation of Silver-Copper Alloys. (In German.) Ernst Justus Kohlmeyer and Karin V. Sprenger. *Zeitschrift fur anorganische Chemie,* **257,** 199-214 (1948) Nov.

Proves experimentally that molten Ag-Cu alloys containing up to at least 30 percent Ag can be completely oxidized at 1230° C. If the alloy contains more than 30 percent Ag, the oxidized melt will contain unoxidized Ag in addition to AG_2O and Cu_2O. The same results are obtained by heating an Ag_2O and CuO mixture to 1230° C. At atmospheric pressure, molten Cu_2O will dissolve up to 44 weight percent Ag_2O. Includes constitution diagrams, graphs, and tables. 18 ref.—BLR.

6.3

Fabrication of Titanium-Rich Alloys: Mechanical Properties of Some Wrought Alloys. E. E. Larsen and others. *Ind. and Eng. Chem.*, **42,** 237-242 (1950) Feb.

Describes melting procedure and furnace used for production of small (1-2 lb.) Ti and Ti-alloy ingots. Fabrication of the billets into specimens suitable for determination of tensile strength, elongation, resistance to oxidation, hardness at elevated temperatures, and resistivity is also discussed. Alloys containing up to 5% Fe, Co, Ni, Cr, Mo, Mn, V, Cu, In, Si, B, Al, Mn-Si, Mn-Al, and Al-Cr were made. Of the ones investigated to date, those containing B, V. W, Fe, Mn-Si and Al-Cr appear to have the highest mechanical properties.—BLR.

6.3, 3.5, 7.10

Some Observations on the Behavior of Platinum, Platinum-Rhodium Thermocouples at High Temperatures. M. K. McQuillan. *Journal of Scientific Instruments and of Physics in Industry,* **26,** 329-331 (1949) Oct.

Effect of heating at high temperatures on the Pt-Rh element of Pt thermocouples was studied. It was found that in air more Pt than Rh is lost by perferential oxidation, and in vacuo, by volatilization. Very little metal is lost on heating in hydrogen. An explanation of those effects hitherto explained by loss of Rh is suggested. Effect of heating Pt wires in a reducing atmosphere in the presence of refractory materials other than those containing silicon was also investigated. Carbon, beryllia and alumina were found to have no contaminating effect.—BLR.

6.3, 3.5

Rapid Oxidation of Metals and Alloys in the Presence of Molybdenum Trioxide. J. L. Meijering and G. W. Rathenau. *Nature,* **165,** 240-241 (1950) Feb. 11.

Authors conclude that the accelerated oxidation of Al-Cu, Cu and Ag and Ag-Al in the presence of MoO_3 at about 500° C is due to the presence of a liquid eutectic mixture of the oxides of Mo and of the basis metal, which prevents the formation of a protective oxide film. See also the paper by Leslie and Fontana noted in B.N.F. Bulletin 234, Dec. 1948, p. 403.—BNF.

6.3

New Nickel Alloy. *Purchasing,* **27,** No. 5, 170 (1949) Nov.

A new Ni alloy which contains no Cu and is free of Fe, designated as Waukesha Metal Alloy No. 23, has high resistance to corrosion, good machinability and freedom from any tendency to seize or gall when used in moving contact with itself or other metals including stainless steels. Metal is available in cast form only. It does not require heat treatment, and in the as-cast condition has a tensile strength of 50,000-60,000 psi, an elongation of 7-10% and a Brinell hardness of 145-165. Mfd. by Waukesha Fdry. Co.—INCO.

6.3, 8.5

Nickel Alloys in Pulp and Paper Making. R. T. Barnes & K. H. J. Clarke, Inco. Paper read at Corrosion Forum and Welding Clinic, Port Arthur, Mar., 1948. *Pulp and Paper Magazine of Canada*, **49**, 69-73 (1948) Apr.

Practical discussion of the types of nickel-containing material suitable for use in pulp processing and paper making. Pulp processing includes wood preparation, digestion and liquor preparation (sulphite pulping, sulphate and soda pulping, caustic recovery handling of sulphite cooking liquors, evaporation of sulphate black liquor), bleaching and brightening (contact with chlorine and hypochlorite, peroxide, zinc hydrosulphate), washing and thickening (in brown stock washers, sulphite pulp washers, groundwood thickening, lime sludge filter dressings), and screening (materials for perforated and slotted screens). Paper making includes materials for stock lines, beaters, and Jordans, Fourdriniers, doctor blades and other auxiliary parts.—INCO.

• Non-Metallic

6.6

Protecting Wood Against Fire and Pests. I. G. Farbenindustrie. PB. 53701, Frames 2268-72; *Prev. Det. Abs.*, **6**, W 60 (1949).

Simultaneous protection against fire and insects is obtained by treatment with fire-proofing agents such as NH_4 fluoborates.—RPI.

6.6

Flame-Proofing Agents and Fire-Inhibiting Coatings. Farbenindustrie. PB. 53734, Frames 2126-9; PB. 32509; Frames 4083-5; *Prev. Det. Abs.*, **6**, W 19 (1949).

The condensation product of sulphamide and CH_2O imparts a water-repellent, flame-proofing finish to yarns, fabrics, paper, wood and straw. Weather-resistant fire-retardant white or colored coatings can be made by mixing the product with kaolin, talc, Ti_2O or colored pigments and an organic binding agent.—RPI.

6.6

Process for Protection of Inflammable Materials. I. G. Farbenindustrie. PB. 65872, Frames 1415-8; *Prev. Det. Abs.*, **6**, W 19 (1949).

The inflammability of paper, wood, etc., can be eliminated or reduced by treatment with an aq. suspension of a condensation product of CH_2O, other aldehydes and NH_4 salts, preferably together with other flameproofing agents, e.g., condensation products of urea, dicyandiamide or guanidine with aldehydes. Wetting agents may also be included.—RPI.

6.6

Intravan U, Camouflage Sealing Material and Standard Fire-Protecting Agent. I. G. Farbenindustrie. PB. 66059, Frames 204-8; *Prev. Det. Abs.*, **6**, W 62 (1949).

Intravan U, the only German flame protecting salt which imparted weather-proofing qualities, was replaced during the war by a standard product FSM-I (Intravan BK) which contained 33% $(NH_4)H_2PO_4$ or $(NH_4)_2HPO_4$, 60% $(NH_4)_2SO_4$ and 7% activator (e.g., 2% salicyclic acid, 5% Leonil S).—RPI.

6.6

Fireproofing H. M. Ships. *Paint Manuf.*, **19**, No. 5, 162, 164 (1949).

Much of the timber used is pressure-impregnated with $NH_4H_2PO_4 + H_3BO_3$ and supplied in bulk, but there is a danger that pieces of varying fire resistance may be obtained when cutting the material. Attempts have been made to fireproof the linoleum used for deck coverings. Cryst. water-soluble salts such as NH_4 or urea phosphate and sulphamate cause difficulty in handling and sheeting the linoleum mix and are not sufficiently protected by the linoxyn from eventual leaching out by H_2O. Insol. basic salts and oxides, e.g., zinc borate, are incompatible with linoxyn and other insol. salts are inactive at low conc. The best results have been obtained by replacing part of the linoxyn by a chlorinated resin and part of the filler by Sb_2O_3. Ship trials are to be carried out with this material.—RPI.

6.6, 8.9

Wood Requirements for Shipbuilding. J. G. Kuenzel. Office of Naval Research, Wood Symposium, 22 pp (1949). *Prev. Det. Abs.*, **7**, W 23 (1949).

Teak was found to be the best decking material, but its high cost limits its use. Composite woods gave good performances. The seasoning checks which lower the bending efficiency of oak can be somewhat mitigated by coating the sides and ends of the freshly-sawn planks with a coating based on mica and spar varnish.—RPI.

6.6

Corrosion-Resistant Masonry Construction. E. E. Ludwig, Dow Chemical Co. *Petro. Ref.*, **28**, No. 1, 79-82 (1949) Jan.

A review of the materials and techniques used in the chemical process industry today is given. Corrosion-resistant brick, cement mortars and plasters are used. Silicate and resin cements are good acid-proof cements and these are coated with concrete paint or asphalt.—INCO.

6.6, 3.3

Results of Experiments on the Effectiveness of Various Preservatives in Protecting Wood Against Marine-Borer Attack. J. D. MacLean. Office of Naval Research, Wood Symposium, 23 pp (1949). *Prev. Det. Abs.*, **7**, W 12 (1949).

Marine borer resistance tests of wood preservatives were carried out over a period of approx. 20 yrs. The most effective preservatives were the higher-boiling creosote oils and creosote fractions, the higher-boiling water-gas-tar creosotes and solns. of coal tar in coal-tar creosote.—RPI.

6.6, 3.3, 5.4

Fungicidal Treatments for Cork Gaskets. Sigmund Berk. *Ind. & Eng. Chem.*, **41**, 627-33 (1949) Mar.

The deterioration of materials such as cork gaskets by fungi under tropical conditions was studied. Seven fungicidal formulations applied to protein and resin bonded cork were evaluated on the basis of a number of criteria for mold-proofing automotive gaskets. 10 references.—RA.

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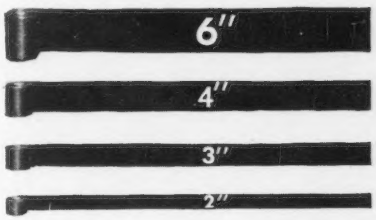

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21a

• Duplex Materials

6.7

Metal-Coated Plastics Combine Advantages of Both Materials. H. R. Clauser. *Mat. & Meth.*, **27**, 79-82 (1948) June.—BL.

EQUIPMENT

• Engines & Turbines

7.1, 3.6, 5.8, 3.4

Service Tests Solve Aluminum Cylinder Head Corrosion Problems. M. W. Daugherty and R. F. Koenig, Aluminum Co. of America (Preprint No. 339, S.A.E. Summer Meet., French Lick (6/5-10/49) 16 pp. $0.25. Abstract, *SAE Journal*, **57**, No. 18, 35-37 (1949) Aug.; *Automotive Inds.*, **101**, No. 1, 44 (1949) July 1.

Two problems formerly associated with the use of aluminum cylinder heads, corrosion at stud clearances and at the coolant inlet ports, have been solved. The basic cause of inlet port corrosion is the fact that the aluminum head has a higher electrode potential than the cast iron cylinder block in practically all coolants. There is considerable evidence in support of the theory that the corrosion is galvanic in nature. Water supplies, and inhibitors used in water to prevent rusting, anti-freezes, erosion and vibration and other minor factors were investigated for corrosive effects. One of the major factors affecting the rate of galvanic attack is the electrode potential of the cylinder head alloy. To achieve the low potential desired, the alloy should contain an adequate concentration of copper, and no more than a few tenths of a percent of zinc. Also, the alloy should be in the as-cast or solution heat-treated condition to retain sufficient copper in solid solution. Proprietary alcohol and ethylene glycol antifreezes, and inhibitors used to prevent rusting of the iron cylinder block, were found to be important accelerators of port corrosion, particularly when mixed with water containing several hundred parts per million of chloride. The preferred non-freezing coolant is water containing at least 50% by volume of any proprietary ethylene glycol anti-freeze. Corrosion at stud clearances can be prevented by the use of cap screws, larger stud clearances, or stud coating compounds. Results of corrosion tests are shown in graphs and photographs.

7.1, 4.4, 5.8, 8.9

Evaluation and Application of Diesel Lube Oils. A. E. Hickel. *Diesel Prog.*, **15**, No. 10, 38-39 (1949) Oct.

Lubricating oil characteristics, heavy-duty detergent type oils, dispersion characteristics, oxidation, inhibitors, bearing failures, additives, heavy-duty Diesel lubricants, foam, Aleman, and caterpillar single cylinder tests, chemical changes in Diesel oils, oil combustion and viscosity index improvers, railroad Diesel engines, and marine Diesel oils are discussed.—INCO.

7.1, 3.6

Thermo-Electric Corrosion — Protection of Kaplan Water-Turbine Runners. H. Krenn. *Electrical Rev.*, **145**, 545-548 (1949) Sept.

Describes examination of water-turbine runners of phosphor bronze, in which cavitation attack was suspected. Erosion found to be due to electrolysis. Remedial measures described.—INCO.

7.1, 5.8, 8.9

Corrosion of Turbine Journals. S. E. Bowrey. *Trans. Inst. Marine Engrs.*, **61**, 57-65 (1949) Apr. *J. Am. Soc. Naval Engrs.*, **61**, No. 3, 664-682 (1949) Aug.

Corrosion inhibiting oils and the proposed water soluble inhibitor, sodium-nitrite is considered. Discussion includes account of laboratory investigations and sea trials of sodium nitrite with details of successful applications of proposals to case of a ship where gearing was already in an advanced state of corrosion.—INCO.

7.1, 3.5

Fly-ash Erosion in Gas Turbines. M. A. Fisher and E. F. Davis. *Mech. Eng.*, (New York), **71**, 481-487 (1949) June.

One of the chief difficulties anticipated in the use of pulverized coal as a fuel for the gas turbine is the possibility of serious erosion of turbine blades and other metal parts by the suspension of fly ash in hot combustion gases. The erosion of metals through the impingement of solid particles suspended in a rapidly moving gas stream is an extremely complicated process which at present cannot be described in exact terms. The high operating temperature of gas-turbine blades introduces special problems in connection with erosion by solid particles. The oxide film which is formed on metal surfaces at high temperatures may well be more brittle and more susceptible to erosion damage than the underlying metal. If this surface film is removed by erosion, exposing more metal to oxidation, then the repetition of this process might lead to a very rapid loss of metal. In addition, the heterogeneous nature of some turbine alloys complicates the situation because the relatively minute particles of fly ash may show a preferential attack on some constituents of the metal structure, resulting in the weakening of stressed parts. In studying the erosion of turbine blades by fly ash at high temperatures, it is thus necessary to investigate possible structural changes and localized damage, as well as the overall loss in metal weight. The authors report that the chief features of all erosion tests at high temperature (800° F to 1350° F) was the formation of hard tenacious coatings or deposits on the specimens. The exact amount and nature of the deposits varied widely according to the fly ash used and the conditions of impingement. In many cases it was found that both deposit formation and erosion took place on different parts of the same specimen, so that the net result varied from a considerable loss of weight of the erosion test specimen under some conditions to rapid weight gains under other conditions. In general, it was found that deposit formation was associated with the impingement of relatively fine ash particles, smaller than about 10 microns diameter, while coarser particles tended to remove any deposits present on the specimen face and to produce erosion of the metal. The deposits produced at high temperature consisted of a hard ceramic-like material ranging in color from a light tan, through various shades of reddish brown, to a dark-red almost black color. Most of the deposits adhered so strongly to the metal surface that they could be removed only with difficulty by using a sharp knife blade. The general appearance and properties of the high-temperature deposits suggested that the fly-ash particles actually were sintered together, even at temperatures as low as 800° F. It appears that the sintering of the fly ash in the deposits must be helped by the pressures developed during impingement as well as by the selective concentration in the deposit of the more plastic constituents of the fly ash.—TIME.

7.1, 6.2, 8.9

Stainless Steel Propellers for Whaling Ships. *The Shipbuilder and Marine Engine-Builder*, **56**, 583 (1949) Aug.

An interesting application of stainless-steel is exemplified in the propellers fitted to many whaling vessels. During the whaling season, the sea in the operational regions is frequently covered by areas of thin ice, interspersed with larger pieces, so that the ships' propellers are exposed to very arduous conditions. Blade damage, caused by impact with large pieces of ice, is a constant danger, while abrasion of the blade surfaces is inevitable. Consequently, propeller replacement is more frequently necessary than in other classes of vessel. Experience has shown that, under such conditions, stainless-steel propellers are especially advantageous. Their resistance to corrosion is not inferior to that of non-ferrous propellers, and the material has the further important merit that its mechanical properties are of a high order. The steel usually employed for such propellers is one containing from 12 to 14 percent of chromium, basically similar in constitution to that employed for stainless cutlery. After appropriate heat treatment, the material, as it exists in a propeller casting, has a tensile strength of between 40 and 45 tons per sq. in. Moreover, the steel combines toughness and ductility to a remarkable degree. An Izod impact value of between 15 and 25 ft.-lb. and an elongation of 25 percent are readily obtainable; while tests have shown that the material may be bent cold, through large angles, without fracture. This combination of properties makes these stainless steel propellers especially suitable for the ice conditions mentioned. Prior to the war, such propellers were manufactured almost entirely in Scandinavian countries, but, in the post-war period, the technique has been developed in this country. Little experience was available in any British foundry in regard to the casting of these propellers, but the problem has been tackled, with conspicuous success, by a Scottish firm of steel founders. Much experience has been gained in the production and finishing of these specialized castings. Due to the greater strength and toughness of the metal, the problems associated with the finishing of the stainless-steel blades to a high standard of smoothness are very different from those which occur with non-ferrous propellers, but great advances have been and are being made, and there is now good reason to believe that the Scottish product compares favorably with that of any other country.—TIME.

7.1, 3.2, 3.5, 8.9

Experimental Investigation of Rim Cracking in Disks Subjected to High Temperature Gradients. P. I. Wilter-

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dink. NACA, Research Memorandum E9F16, Sept. 1, 1949, 45 pages.

Results on investigation of the above in a welded-blade composite gas-turbine wheel, in two carbon-steel disks, and in five tool-steel disks are presented. In order to determine the effectiveness of holes in preventing crack propagation, ⅛ and 1/16-in.-diam. holes were drilled in the rim. The effectiveness of the holes in preventing crack growth was difficult to estimate accurately. Influence of hardness and various types of notch was investigated by subjecting 13.5 in. disks to thermal-stress cycles.—BLR.

• Heat Exchangers

7.4, 6.3, 3.7

Comparative Corrosion Resistance of Some Copper Alloy Condenser Tubes. J. R. Freeman, Jr., and A. W. Tracy, Am. Brass Co. *Corrosion,* **5,** No. 8, 245-248 (1949) Aug.

Report of tests designed to determine relative resistance to corrosion, particularly by impingement, attack of a series of condenser tube alloys under relatively extreme conditions of service. Copper-nickel alloys containing iron show a marked superiority in resisting the extreme test conditions. A new alloy containing 0.75 iron in 90%, copper-10% nickel is superior to 8% tin bronze.—INCO.

7.4

Fouling of Marine-Type Heat Exchangers. H. E. Bethon (Navy Dept.). Paper before ASME, Heat Transfer Div., Ann. Mtg., New York, Nov. 28-Dec. 3, 1949, Paper No. 48-A-145. *Trans. ASME,* **71,** No. 7, 855-869 (1949) Oct.

Discussion emphasizes the importance of making due allowance for fouling and cleaning in the initial design of heat exchangers for naval service. It describes briefly the design and construction of marine-type heat exchangers in addition to various design and operating procedures which affect fouling characteristics.—INCO.

7.4

External Corrosion of Furnace-Wall Tubes. R. C. Corey, H. A. Grabowski, B. J. Cross, Paper before ASME, 1948. *Combustion,* **20,** No. 6, 53 (1948) Dec.

Furnace-wall tubes are attacked by SO_3 and deposits of FeS are left on the wall and cause corrosion by the alkali-metal sulfate type of deposit.—INCO.

7.4, 3.5

External Corrosion of Furnace-Wall Tubes. III. Further Data on Sulphate Deposits and the Significance of Iron Sulphide Deposits. R. C. Corey, G. A. Grabowski and B. J. Cross. *Trans. ASME,* **71,** 951-962; discussion, 962-963 (1949) Nov.

Extended studies begun in 1942 show that liquid alkali-metal pyrosulfates can be formed under operating conditions from deposits of alkali-metal sulfates on the tubes. Rate of attack will be considerably higher than when the sulfates, or "enamel" deposits, do not form a liquid phase. Phase boundaries for three compositions were established. Conditions for thermal decomposition of coal ash, leading to formation of the SO_3 necessary for the corrosion process, were determined. Furnace-wall-tube attack, associated with deposits consisting mainly of FeS, is believed to be related to deposition of pyrites on the tubes. Relationship between laboratory results and observations of furnaces before and after application of preventjve measures are described.—BLR.

7.4, 3.7

High Creep Strength Austenitic Steel Tubes. G. T. Harris and W. H. Bailey. *Metallurgia,* **38,** No. 226, 189-192 (1948) Aug.

Discussion of development of heat resisting steel tubes for use in heat exchangers which form an essential part of gas turbines for land and marine use. Jessop G.18B steel tubes containing 13 nickel, 13 chromium, 2.5 tungsten, 2.0 molybdenum, 3 niobium, 10 cobalt, 1 silicon, 0.8 manganese and 0.4 carbon is discussed with regard to manufacture of the tubes, general examination, mechanical properties and welding characteristics. Table is given of creep strength of G.18B steel for specified strains, times and temperature. Effect of heat treatment on microstructure of G.18B tubes is shown.—INCO.

7.4, 3.7, 3.2

Iron Changes Corrosion Resistance of Copper-Nickel-Iron Alloy Tubes. W. Lynes, Revere Copper & Brass, Inc. *Power,* **93,** No. 11, 84-85 (1949) Nov.

Discussion of how and why of condenser tube behavior in regard to pitting, corrosion and impingement. Alloy make-up determines suitability of tubes for use with certain water conditions. Sometimes a compromise must be made among properties. At 10 Ni level, impingement resistance increases rapidly with increase of Fe up to about 0.75% instead of 0.3% as with alloy containing 30 Ni. Pitting tendency in 10 Ni also increases with increase of Fe content. Substantially larger amounts of Fe may be tolerated than in 30 Ni alloy. Up to about 2 Fe may be present without likelihood of inducing a damaging tendency to pit.—INCO.

7.4, 8.4, 3.7, 3.2

Admiralty Condenser and Heat-Exchanger Tubing in Oil-Refinery Service. Wilson Lynes. *Petro. Eng.,* **21,** No. 12, C-42-47 (1949).

Observations over a number of years have confirmed the effectiveness of small additions of arsenic, antimony, and phosphorus as a means of inhibiting the dezincification of Admiralty metal tubes in condensers and heat-exchangers. Other causes of failure of tubes are intergranular corrosion and stress-corrosion, but these are uncommon in both oil-refinery service and power stations. Transgranular cracking is uncommon in power stations, but it is an important cause of failure in oil refineries, where the tubes often operate under conditions favorable to corrosion-fatigue.—MA.

7.4, 6.3

Tough Alloy for Condenser Tubes. *Marine Eng. & Shipping Rev.,* **53,** No. 9, 90 (1948) Sept.

Discussion of the testing of 70/30 Cu-Ni alloy developed primarily for condenser tube service in ship and shore power plants. This alloy has proved useful for large diameter piping and water boxes. In addition to its corrosion resistance, 70/30 Cu-Ni resists fouling, stress corrosion cracking, pitting and erosion. Inco tested the specimens at Kure Beach.—INCO.

• Containers

7.5, 8.9, 6.4, 6.2

Long-Term American Tests of the Corrosion-Resistance of Light-Alloy and Steel Coal Hoppers. J. Reinhold. (In French.) *Rev. Aluminum,* **26,** No. 156, 201-205 (1949) June.

An account of experiments by Alcoa from 1932 to 1944, which showed that hoppers of different aluminum alloys remained substantially uncorroded by various coals after 12 years, while copper-steel hoppers were badly corroded.—BNF.

7.5, 8.4, 6.4

Internal Corrosion of (Aluminum) Crude-Oil Tanks. R. A. Brannon. *Petro. Eng.,* **21,** No. 7, D22-D25 (1949).

A review of the corrosion problems encountered in tanks containing sour crude oil. To combat vapor-space corrosion, aluminum roofs and roof-supporting structures have been used, and it appears that its use in this field will be extended.—MA.

7.5, 8.9, 6.4

A Large-Capacity Light Metal Goods Van After Ten Years' Service. P. Brenner. *Aluminum-Beratungsstelle: Aluminum im Verkehrswesen,* **1950,** 25-26.

A railway van built up of a frame of age-hardened Pantal alloy (AlMgSi) with welded walls and roof of aluminum-magnesium-manganese alloy (cf. Auchter, *Aluminum,* **21,** 517 (1939); *Met. Abs.,* **6,** 387 (1939) was used for the transport of alumina (9 years) and of sodium carbonate (1 year) and afterwards examined. The light metal was unprotected by paint, but no corrosion (even at the welds) was observed, with the exception of some small local areas where steel rivets had been used. But all the steel parts, such as rivets, screws, handles, hinges, etc., were badly corroded.—INCO.

7.5, 8.4, 5.2

Corrosion Mitigation Within Dehydrating Tanks. E. O. Kartinen, Signal Oil & Gas Co. Paper before AIME, Los Angeles. *Oil & Gas J.,* **48,** No. 31, 82-84 (1949) Dec. 8.

The type of corrosion which occurs in the water-exposed areas of dehydrating tanks, and, to a lesser degree, in some stock tanks is discussed. Operational difficulties, and the question of whether a forced drainage or a galvanic anode drainage system would be used are included.—INCO.

7.5, 4.3, 6.1

Materials for Bromine Containers. G. S. Haines, Food Machinery & Chem. Corp. *Ind. Eng. Chem.,* **41,** No. 12, 2792-2797 (1949) Dec.

Nickel and Monel were found to be satisfactory container materials for dry Br_2 and were accepted as such by Interstate Commerce Commission. Br_2 of satisfactory dryness can be prepared by passing it through H_2SO_4 of 60 weight percent concentration or greater. Dissolved metallic impurities in the Br_2 are limited by solubility to about 1 ppm. Teflon is very resistant to attack by Br_2 and is suitable as a gasket material in this application. Other materials tested included high carbon steel, lead, Haynes Stellite 19-P, and Hastelloys A, B, and C.—INCO.

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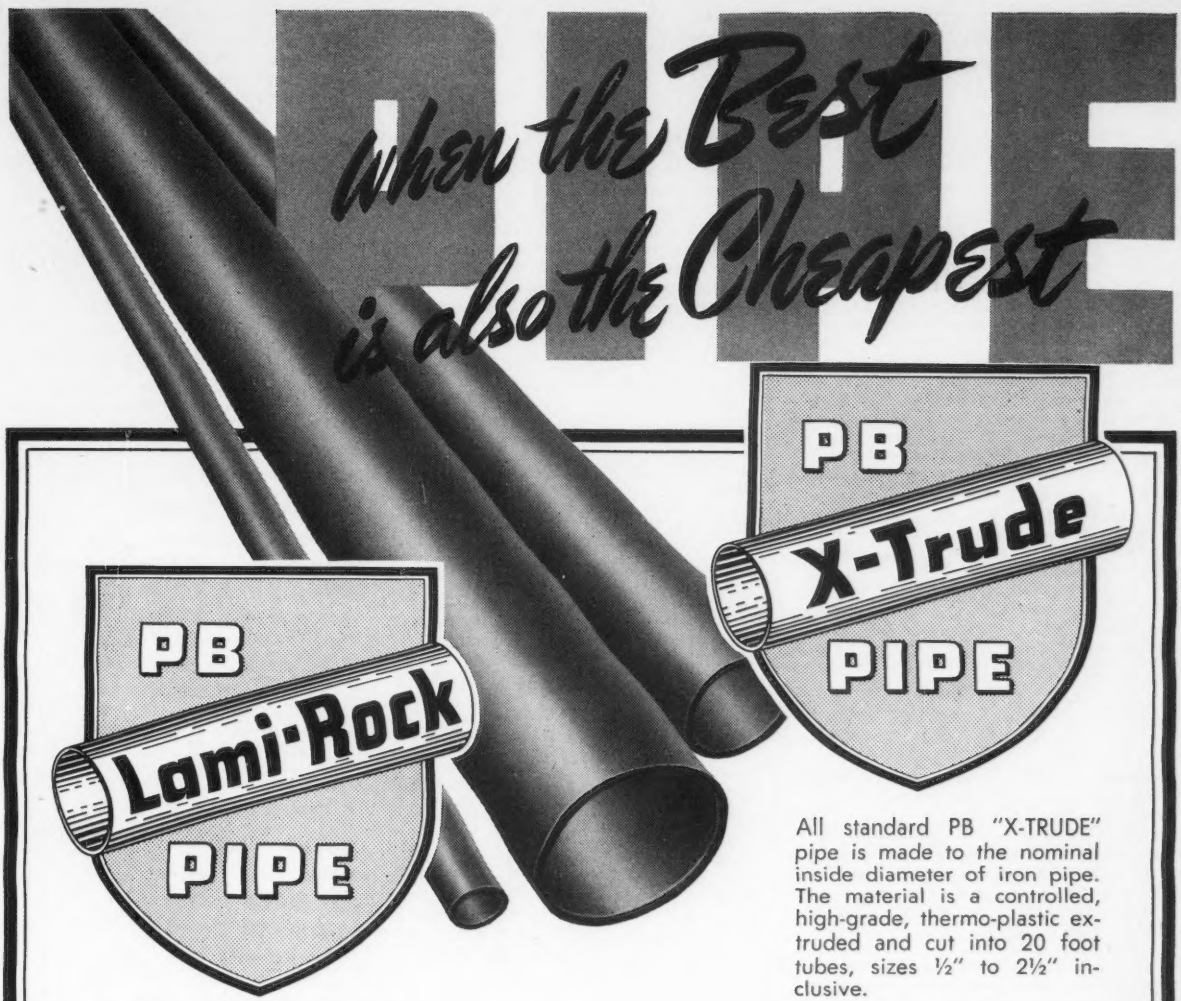

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• Electrical & Telephone

7.7, 5.8, 4.4

Liquid Dielectrics for Transformers. J. G. Ford, Westinghouse Elec. Corp. *Electrical Eng.*, **67**, No. 11, 1066-1071 (1948) Nov.

The use of inhibitors has been demonstrated well in lubricating oils but has been limited in transformer oils. Phenolic, amino, or sulfur compounds have worked well in laboratory tests or in trials in pilot transformers but are expendable and, once used up, behavior of the oil is very similar to that of uninhibited material. The use of synthetic inhibitors commercially becomes difficult. Insulating oils from different sources may have been subject to different degrees of refinement. When combined in a common storage tank, life in transformers is unpredictable. Mixture of these oils before or during service involves complications. Additions of inhibitors to partially oxidized oil is questionable in view of the many types of oil in service and the limited information available to date.—INCO.

7.7

A 138,000-Volt Polyethylene-Sheathed Compression Cable-Pipe Line Type. J. E. McCormack and others. *AIEE, Trans.*, **67**, Pt. 1, 447-465; disc. 465-474 (1948).

References.—BL.

7.7, 3.6

Corrosion in Multiple Layer Wound Coils. II. Howard Orr. *Communications*, **29**, 18-19 (1949) July.

Part II of report on progress achieved in overcoming electrolytic corrosion in multiple layer coils; describes tests used to determine characteristics of corrosion. (Part I appeared in Jan. issue.) (To be continued.)—BLR.

7.7

Bridge Erosion in Electrical Contacts and Its Prevention. W. G. Pfann. *AIEE Trans.*, **67**, 1528-1533 (1948); and Bell Tel. System, Tech. Publ., **B1621**, 6 pp. (1948).

Low-voltage currents below 10 amp. between precious-metal contacts when broken tend to form bridges of molten metal, then craters on each contact. The effect of this on the erosion and also on the building-up of contacts is explored, and it is shown how for certain combinations of metals (or alloys) and current ranges the process may be self-limiting, leading to a steady condition of wear. Platinized copper contacts, if the platinum layer is of suitable thickness, may reach an equilibrium of this type. The disturbing effect of inductance in the circuit is mentioned, but not discussed in detail.—MA.

7.7, 4.2, 5.4

Investigation and Research Pertaining to the Development of the Process of Impregnation to Withstand All Types of Atmospheric and Climatic Conditions Relating to Rotating Electric Machinery. M. Tenzer and E. E. Boyno. U. S. Signal Corps., Contract No. W-36-039-sc-32370. Final Report, **1**, 118; (1948); *Prev. Det. Abs.*, **6**, E 31 (1949).

Results are given for various materials undergoing a series of weathering cycles. Materials included Fiberglas, silicones, insulating tapes and varnishes.—RPI.

7.7, 5.2

Corrosion Testing of Buried Cables. T. J. Maitland, Amer. Telephone & Telegraph Co. Paper before NACE, 5th Ann. Conf., Cincinnati, April 11-14, 1949. *Corrosion*, **6**, No. 1, 1-8 (1950) Jan.

Corrosion testing methods employed in connection with buried toll cables of various types of construction are discussed. The frequency of test points, method of selection, type of instruments used and method of analyzing results obtained are outlined. Few typical examples illustrating the results of corrosion tests on Cu and non-Cu jacketed cable, and the protective measures, such as cathodic protection, used to correct unsatisfactory conditions together with results obtained are given.—INCO.

7.7, 8.2, 1.7

Protective Covering for Lead-Sheath Power Cables. C. T. Nicholson and G. H. Fiedler, Rochester Gas & Elec Corp. *Elec. Eng.*, **69**, No. 3, 223-225 (1950) Mar.

Last spring, the Sheaths and Coverings Sub-Committee of the Insulated Conductors Committee mailed questionnaires to representative cable users and manufacturers in order to determine their views on the use of protective jackets with lead-sheath cable. Most of those responding recommend neoprene hose and plastic jackets for prevention of corrosive action, and some believe that these coverings may protect lead-sheath cable from mechanical damage.—INCO.

• Wires & Cables, Non-Electrical

7.8, 8.10

Corrosion and Protection of Mine Hoist Ropes. F. L. LaQue. *Corrosion*, **6**, 8-13 (1950) Jan.

Presents results of detailed investigation of the above. Includes photographs of cross sections of new "rope" (steel cable) and of rope after various amounts of use, showing wear and corrosion existing at various distances from the drum spout. Size-reduction, elongation, and breaking-strength variations along the rope from drum to cage are shown graphically.—BLR.

• Miscellaneous

7.10, 8.6

Rotameters in the Viscose Rayon Industry. T. G. Hicks. *Rayon & Synthetic Textiles*, **30**, No. 11, 51-53 (1949) Nov.

Brass fittings and No. 303 stainless steel floats are used in rotameters measuring water flow rates in textile mills. In rotameters measuring acid flow from adjustment tank to spinning machine, float Hastelloy C or porcelain, to prevent instrument corrosion. Rotameter fittings for 3% NaOH solution are usually made of iron and steel, the float of No. 303 stainless steel. Proper applications require use of corrosion resistant materials and an instrument with a suitable flow range.—INCO.

INDUSTRIES

• Group I

8.1

Leaky Walls Endanger Steel Buildings. B. Brown. *Eng. News-Record*, **143**, No. 28, 42-43 (1949) Dec. 8.

Examples of advanced corrosion in steelwork of buildings no more than 40 years old is given, the trouble coming from leaky exterior walls of brick. This condition is found in poorly constructed homes and in locations where low temperatures and driving rains are common. Recommendations for better construction on all new structures are given.—INCO.

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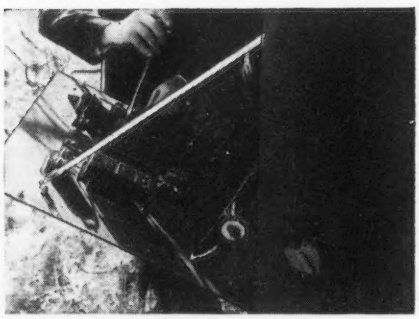

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8.1, 6.4

Cast-Aluminum Panels Comprise Building's Exterior. *Foundry*, **77**, No. 10, 134 (1949).

Describes the use of cast aluminum panels backed with diatomaceous earth, for the walls of a large steel-framed building.—MA.

8.1, 6.1

The Corrosion of Metallic Materials in Building. J. Friedli. (In German.) *Schweiz Arch. angew, Wiss. Techn.*, **15**, No. 9, 261-265 (1949).

F. discusses the corrosion of metals used in the construction of buildings by other materials with which they come into contact. Shows that chemicals (especially chlorides) added to mortar and to cement, and the presence of moisture, are the most important factors in corrosion of ferrous and non-ferrous metals. A number of examples are given. The relative resistances of copper-, aluminum-, zinc-, and lead-base alloys and of ferrous alloys, to corrosion by 20 common materials used in building, are tabulated; among the 20 building materials are mortar, cement, wood, water, asphalt and bitumen.

8.1, 4.6, 5.8

Anticorrosion Measures Necessary in Air Conditioning Systems. Joseph I. Montel. *Refrig. Eng.*, **57**, 346-7, 384 (1949) Apr.

Chemical treatment is often required for those parts of air conditioning systems which cannot be protected by corrosion resistant paints. A list of such parts is given. Data are presented showing the advantages of automatic continuous chemical treatment over intermittent manual treatment. Test methods are described briefly without giving specific details as to treatments used or recommended.—RA.

8.1, 4.6, 5.8

Corrosion Can Be Controlled in Refrigeration Systems. Joseph I. Montel. *Refrig. Eng.*, **56**, 35-8 (1948) July.

In a raw water supply there are fixed relationships between alkalinity, carbon dioxide and pH. Corrosion can be inhibited by controlling these factors. Air conditioning water systems are used for washing, cooling, heating and/or condensing purposes, and can be classified as 1) once-through system, 2) closed recirculating water systems and 3) open recirculating water systems. In recirculating systems it is desirable to maintain a pH of 8 and a sodium chromate concentration of 500 ppm either by manual dosage or by means of a chemical feeder. For calcium chloride brines, 2000 ppm sodium chromate is recommended; for sodium chloride brines, 4000 ppm. Diagrams of various systems are presented and other aspects of corrosion discussed. —RA.

• Group V

8.5, 7.8, 5.7

Some Recent Developments in Kraft Recovery—I—II. T. T. Collins, Jr., & P. H. West (Thilmany Pulp & Paper Co.) *Paper Trade J.*, **129**, No. 9, 19-22; No. 10, 25-29 (1949) Sept. 1 & 8.

Jets in venturi atomizer lasted for quite a while until a large excess of free sulfuric acid above a normal salt cake makeup was added to the black liquor and then liquor pipes started corroding within 3 or 4 days. Stainless steel 304 makes good liquor pipes but gases ahead of venturi atomizer pitted the outer surfaces of pipes. A check on stainless 304 indicates it is not the proper material to use and other stainless steels have been recommended. A 14-gauge 304 stainless liner inside atomized throat is necessary. The all-iron gate valve used to regulate amount of liquor going to atomizer was another weak spot but replacement with a 304 stainless gate valve eliminated this wear. One of the steps to combat corrosion was to add soda ash at intervals to scrubber liquor pump tank so as to maintain pH of liquor between 8 and 9. When quantity of sulfur gases is reduced, corrosion in equipment is reduced by liquor oxidation. 6 references.—INCO.

8.5, 6.7

Corrosion in the Manufacture of Alkaline Pulp. F.L. LaQue &. K. H. J. Clark (Inco). Paper before Canadian Pulp & Paper Assn., Tech. Sec., Ann. Mtg., Montreal, Jan. 26, 1949. *Pulp & Paper Mag. Can.*, **50**, No. 3, 10 pp. (1949).

Provides information on the behavior of metals and alloys including Monel, nickel, Inconel, Ni-Resist, nickel-chromium stainless steel, Type 430 stainless steel and Hastelloy C, when subjected to the action of the corrosive solutions encountered in the manufacture of alkaline pulp and the recovery of the chemicals used.

• Group IX

8.9, 6.4

Use of Aluminum Alloys on Railway Coal Cars. Jean Herenguel. (In French.) *Revue de l' Aluminum*, **26**, 195-201 (1949) June.

Metal Fabrication and Uses. Presents results of experimental tests in which side panels were replaced by "Durcilium" and "Alumag 50" panels. Examination after 21 mo. service revealed that the panels had not suffered from corrosion. Mechanical resistance to shocks was good.—BLR.

8.9, 7.5, 4.3

Barges for Transportation of Acids. *Marine Eng. and Shipping Rev.*, **54**, 56-57 (1949) Aug.

For the river transportation of hydrochloric acid The Dow Chemical Co. has recently placed in service five new barges specifically designed for this purpose. Each of the new vessels, which are 195 feet long, 35 feet wide and 11 feet deep, has four rubber lined tanks with a total capacity of 1000 tons of hydrochloric acid. The tanks are positioned in the hold so that the four domes are located in the center of the barge. A steel platform is built around the domes for a working area used during loading and unloading. The platform slopes outboard on either side of the centerline, so any spillage will drain overboard. A coaming around the platform floor prevents acid from draining into the hold. There is a railing on the platform and the stairs to the deck for the safety of the workmen. Tar and sand have been applied to the barge deck plating below the platform to prevent slipping. The barges are designed for easy towing, having a 30-feet bow rake and a deep transom stern. They are of welded steel construction throughout and specially strengthened to withstand "rough" operations in the Intracoastal Waterways where sharp bends and narrow channels cause vessels to sideswipe the canal banks. Eight steel-plate rubbing plates are welded to the sides of the barges at points where contact with other barges or lock walls is most frequently made. The tanks, 12 feet in diameter and 73 feet long, are strapped in steel saddles anchored to the floor of the hold. Seven saddles are provided for each tank.—TIME.

8.9, 5.1

Focus on Materials and Design to Stop Corrosion. Papers before SAE, Eng'g Materials. Session, Summer Mtg., French Lick, June 7, 1949. *SAE J.*, **57**, No. 7, 60-61, 64 (1949) July. See also Automotive Corrosion Clinic, *SAE J.*, **57**, No. 8, 29-37 (1949) Aug.

Papers include:

- Corrosion Problems of the Automotive Engineer by F. L. LaQue and E. L. Hergenroether (Inco).
- Corrosion of Electroplated Steel in Automotive Applications by H. A. Pray (Battelle Mem. Inst.)
- Service Tests Solve Aluminum Cylinder Head Corrosion Problems by M. W. Daugherty and R. F. Koenig (Alco).

Armed with research reports on how and why corrosion deteriorates metals, engineers suggested three ways to suppress it: right material, coatings and inhibitors, and design modifications. Discussion includes steel chemistry, how parts corrode, underbody corrosion remedies, use of alloys to add resistance, and radiator cooling problems.

8.9, 7.5

S. S. Mobilude. *Heat Eng.*, **23**, No. 3, 42-44 (1948).

The S. S. Mobilube, now owned by the Socony-Vacuum Oil Co., was built in 1939 and was torpedoed near Sydney in 1943. The torpedo struck at the water line, exploding under the port boiler. Both the boiler and the engine rooms were completely flooded, but the ship did not sink. Towed to Sydney, she was requisitioned by the Navy and used as a towed floating oil storage receptacle. When declared surplus in 1946, the vessel was at Subic Bay, Philippines, and upon being purchased by Socony-Vacuum, was towed to San Francisco for reconditioning. The starboard boiler had been used as a donkey boiler while the ship was in barge service and under the stress of war conditions had not been properly handled. It is probable that a drying out fire had not been lit for a considerable time after the fire room had been pumped out. Extensive corrosion of boiler and superheater tubes necessitated complete retubing.—TIME.

8.9, 5.4, 7.2, 2.4, 5.2

Development of Pipe Line Coatings and Mechanical Application Methods. S. D. Day. Paper before Short Course on Gas Technology, Tex. Col. of Arts and Industries, Kingsville, June 4, 1948. *Corrosion*, **5**, No. 7, 221-226 (1949) July.

General article discusses pipe coatings in use, coal tar enamels, asphalts, petroleum compounds or greases, bituminous mastics and application methods. Mileage of pipe lines in this country is given as—379,700 miles with 230 000 miles in gas service. 70% of all pipe in service is protected, including pipe used within building walls. Developments in coating materials, final application equipment, electrical inspection or testing, cathodic protection and general know-how in combination results in more nearly corrosion-proof pipe lines for gas and related industries.—INCO.

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8.9, 4.2, 5.3

Corrosion of Electroplated Steel in Automotive Applications. H. A. Pray. Soc. Automotive Engr. Preprint, 1949, 5 pp. Obtainable from Society of Automotive Engineers, Inc., 29 West 39th Street, New York 18. 50c. A condensed version of this paper appears in *SAE J.*, **57**, No. 8, 29-37 (1949) Aug.

Reports atmospheric exposure tests (at six sites) on high-carbon steel specimens plated with composite copper/nickel/chromium or nickel/chromium coatings, various plating and buffing procedures being tried. At one site the specimens were also periodically treated with salt solution, to stimulate winter driving conditions. Results indicate that nickel thickness is the important factor, but the coating life also depends on the type of atmosphere and other service conditions.—BNF.

8.9, 5.4, 7.2

New Method for Internally Cleaning and Coating Pipe Lines in Place. D. H. Stormont. *Oil & Gas J.*, **48**, No. 26, 66-67+ (1949) Nov. 3.

In new method utilizing compressed air as means of propulsion, cleaning is accomplished with chemicals, steel lathe cuttings and other mechanical devices. After cleaning and drying, one primer coat is applied, and dried. Then, one plastic top coat is applied. Since coating is applied under pressure, existing small leaks resulting from internal corrosion likewise are plugged during the course of application. Industrial applications are described.—INCO.

8.9, 6.4, 7.2

Aluminum Pipe Under Test for Oil-Field Use. R. B. Tuttle, *Petro. Interam.*, **7**, No. 7, 40-1 (1949) July.

Experiments are under way to test the ability of aluminum pipe to resist internal corrosion by sour crudes and external corrosion by soils in oil fields. Replacing a section of severely corroded steel pipe, the aluminum portion in the longer steel pipe system includes one-half mile of 6-in. and one-half mile of 4-in. pipe. The joint welding process employs an electrode which does not enter the molten state to become the deposited filler metal. Instead it functions strictly to initiate and maintain an arc in which the filler metal, aluminum alloy, is melted and fused to the pipe material. Specifications of aluminum pipe are listed.

• Group X

8.10, 5.5

Lubrication of Underground Mining Machinery. *Lubrication*, **1948**, Jan. *Canadian Mining J.*, **69**, No. 3, 63-74 (1948) Mar.

Lubricating research has improved the rust-preventive oxidation resisting and heat resisting qualities so that modern lubricants are more durable and give better protection to machinery used in underground mining. Mention is made of the lubrication of wire ropes on mine hoists.—INCO.

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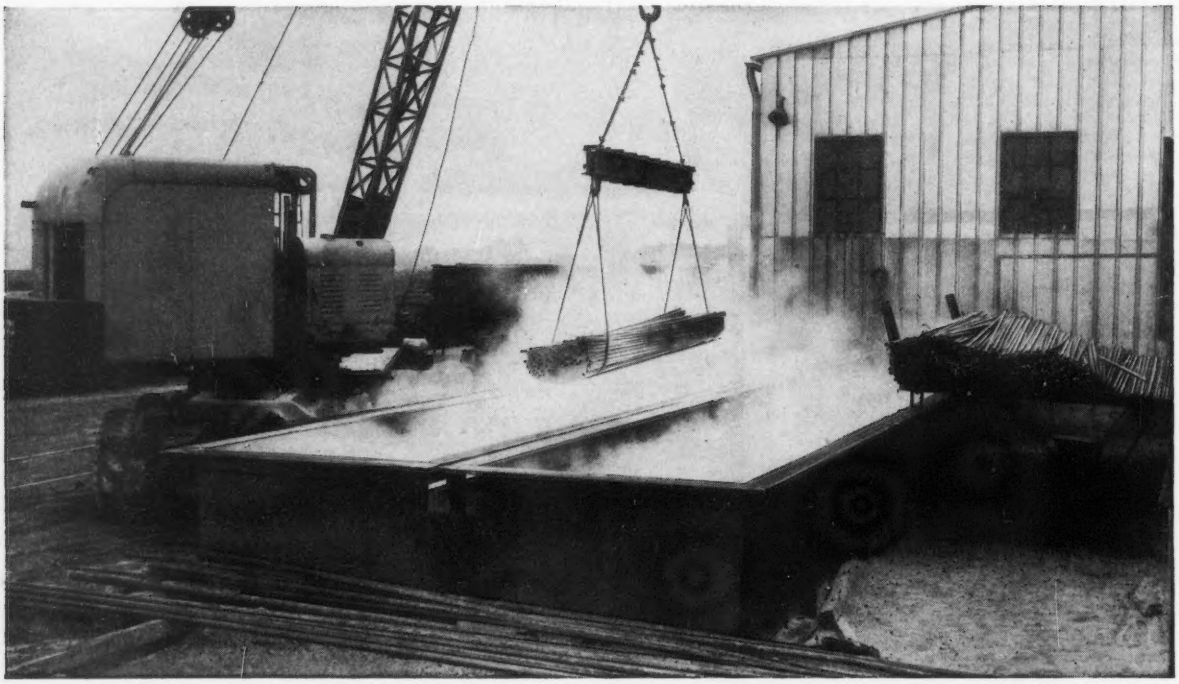
First cost often doesn't tell the whole story! It omits the *major* expense of too many pipe-protection jobs—the cost of maintenance. That is why today's corrosion engineers insist on investigating *every stage* of a protection process before placing a job. They have learned that the *life* of the pipe—the years it can resist every corrosive agent—depends upon how soundly the pipe is conditioned and how scientifically the protection is applied.



WHAT'S HAPPENING HERE is just the first step in Hill, Hubbell's exclusive *controlled* process of pipe protection. Bare pipe is dipped in hot caustic solution to remove every trace of cutting oil and grease. Then it is rinsed in clean hot water, ready for the drying oven and the Hill, Hubbell-engineered Roto-Grit-Blast cleaning and etching machine.

Only this kind of conditioning can prepare pipe for *positive* bonding of the protective layers. And only the skillful *factory* application of these layers can assure the long-range service that keeps protection costs low.

Hill, Hubbell and Company

Division of GENERAL PAINT CORPORATION

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30a

Choosing tower packing for efficiency and long life...

With critical shortages imminent in almost every heavy industry, the question of what tower packing material to use warrants the most careful forethought.

To the requirement of optimum performance now must be added *durability* . . . replacements may be hard to make in the years ahead.

The various tower packing forms developed from Nickel, Inconel® and Monel® deserve your special consideration. All three metals possess high strength, wettability, and high resistance to attack by many fluids processed in packed towers.

Metal tower packing offers five basic advantages that serve to increase tower efficiency:

1. **Low weight per unit volume.**
2. **Large surface per unit volume.**
3. **Large percentage of open area.**
4. **Small weight of liquid retained.**
5. **Corrosion resistance.**

If you need help in selecting a satisfactory metal tower packing material, Inco's Corrosion Engineering Service will gladly make recommendations. Simply write, outlining your problems.

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Berl saddle type tower packing, produced in Inco Nickel Alloys and other metals, supplied by Wire Cloth Products, Inc., Chicago, Ill. Packing of this type has given excellent results in pilot towers. It compares favorably in cost with other forms of packing.

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Although Nickel and Nickel Alloys are currently in short supply, INCO advertisements will continue to bring you news of new products, applications, and technical developments.

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march in new york

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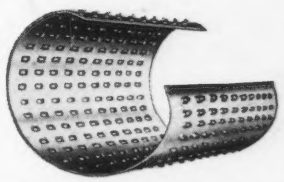
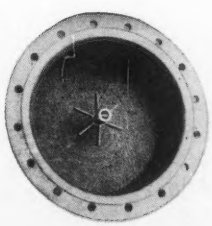


Diagram of protruded packing made by Scientific Development Company, State College, Pa. The individual pieces are small, yet have a large free cross-section. Made in Nickel, Type 316 Stainless Steel, and other metals (on special order).

Heart of a fractional liquid extraction unit comprising a mixing and settling section. The settling section is packed with knit Monel wire mesh. With knit tower packing, open areas from 90% to 98% are obtained, with surface areas up to 200 square feet per cubic foot of packing. Courtesy Otto H. York Co., Inc., East Orange, N. J.



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